HANDBOOK
of
CIRCULATION

Analysis and Compilation by

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Edited by

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Prepared under the direction of the Committee
on the Handbook of Biological Data

DIVISION OF BIOLOGY AND AGRICULTURE
THE NATIONAL ACADEMY OF SCIENCES
THE NATIONAL RESEARCH COUNCIL

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Foreword

The Handbook of *Circulation* is the tenth in a series of publications*, each containing information, chiefly tabular, in one or more fields of the *biological sciences*. These handbooks have been prepared under the general direction of the Committee on the Handbook of Biological Data, Division of Biology and Agriculture, National Academy of Sciences-National Research Council.

The information for the present Handbook was prepared and contributed by leading authorities in the field of circulation. The data were assembled, tabulated, and edited by the Handbook staff, then critically reviewed and authenticated by experts in the areas covered in this volume.

On behalf of the Committee, acknowledgment is made to the numerous scientists who have been so liberal with their time and advice; to Wright Air Development Center United States Air Force, the National Institutes of Health of the Public Health Service, the Division of Biology and Medicine of the Atomic Energy Commission, the Office of Naval Research, the Office of the Surgeon General of the Army, and the Army Chemical Center, for generous support and cooperation which have made possible the production of this book. The Air Force participation in this undertaking was carried out under Contract No. AF 33(616)-3972 with the National Academy of Sciences. Dr. J. W. Heim, Aero Medical Laboratory, Wright Air Development Center, served as contract monitor.

*Handbooks published 1949-1959

Standard Values in Blood	1951
Standard Values in Nutrition and Metabolism	1953
Handbook of Biological Data	1956
Handbook of Respiration	1958
Handbook of Circulation	1959
Handbook of Toxicology, Vol. I, Acute Toxicities	1955
Handbook of Toxicology, Vol. II, Antibiotics	1957
Handbook of Toxicology, Vol. III, Insecticides	1959
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Introduction

The Handbook of Circulation is presented as the companion volume to the Handbook of Respiration*. Its purpose is to make available in a single, comprehensive compilation useful data on circulation, organized for ready reference in the form of tables, graphs, diagrams, and drawings. Contents of this volume have been authenticated by 326 leading investigators in the field of physiology. The review process to which the tables have been subjected was designed to eliminate, insofar as possible, errors of transcription and material of questionable validity.

An explanatory headnote, designed to serve as an introduction to the subject matter or to justify the inclusion of controversial material, occasionally precedes a group of tables. Single tables, however, are usually prefaced by a short headnote containing such important information as abbreviations, definitions, units, methods, and conditions of measurement, and estimate of the range of variation. In order to interpret the data properly, it is essential that the related headnote be read with care.

Appended to the tables are the names of the contributors and a list of the literature citations. The reference abbreviations conform to the LIST OF ABBREVIATIONS FOR SERIAL PUBLICATIONS, Fourth Series, Volume X, Army Medical Library, Washington, D. C. (U. S. Government Printing Office, 1948), and the 1955 SUPPLEMENT thereto. Abbreviations for publications issued after 1955 were constructed from the "Dictionary of Abbreviated and Contracted Words" in the SYNOPSIS OF STYLE, Fourth Series, Volume II, Army Medical Library, Washington, D. C. (U. S. Government Printing Office, 1937).

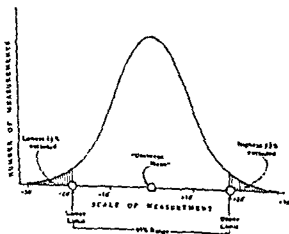
Occasionally, differences in values for the same specifications, certain inconsistencies in nomenclature, and some overlapping of coverage may occur among tables. These result not from oversights or failure to choose between alternatives, but from the deliberate intention of the Handbook Staff to respect the judgment and preferences of the contributor. On the other hand, each table, with few exceptions, is internally consistent.

Values are generally presented as a mean and the lower and upper limit of the range of individual values about the mean. This range may be estimated in several ways, the method depending on the information available. Letter designations (a, b, c, d) identify types of ranges in descending order of accuracy.

(a) When the group of values is relatively large, a 95% range is derived by curve fitting. A recognized type of frequency curve is fitted to a group of measured values, and the extreme 2.5% of the area under the curve at each end is excluded (see illustration)

(b) When the group of values is too small for curve fitting, as is usually the case, a 95% range is estimated by a simple statistical calculation. Assuming a normal symmetrical distribution, the standard deviation is multiplied by a factor of 2, then subtracted from and added to the mean to give the lower and upper range limits

(c) A less dependable, but commonly applied, procedure takes as range limits the lowest value and the highest value of the reported sample group of measurements It underestimates the 95% range for small samples and overestimates for larger sample sizes, but may be used in preference to the preceding method where there is marked asymmetry in the position of the mean within the sample range



(d) Another estimate of the lower and upper limits of the range of variation is based on the judgment of an individual experienced in measuring the quantity in question. The trustworthiness of such limits should not be underestimated

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* Handbook of Respiration. 1958. National Academy of Sciences-National Research Council. W. B. Saunders, Philadelphia

Abbreviations and Symbols

MEASUREMENT

yr = year
mo = month
wk = week
da = day
hr = hour
min = minute
sec = second
msec = millisecond

wt = weight
lb = pound
g = gram
kg = kilogram
mg = milligram
µg = microgram
mEq = milliequivalent
M = mole
mM = millimole
µM = micromole

ht = height
mi = mile
ft = foot
in. = inch
m = meter
cm = centimeter
mm = millimeter
µ = micron

g-m = gram-meter
g-cm = gram-centimeter
kg-m = kilogram-meter

sq in. = square inch
sq m = square meter
sq cm = square centimeter
sq mm = square millimeter
sq µ = square micron

L = liter
ml = milliliter
µL = microliter
cu cm = cubic centimeter
cu mm = cubic millimeter
cu µ = cubic micron

v = volt
kv = kilovolt
mv = millivolt
Å = Ångström unit

ppm = parts per million
rpm = revolutions per minute
av = average

vol % = volumes per cent
g % = grams per cent
mg % = milligrams per cent

°C = degree Centigrade
°F = degree Fahrenheit
> = greater than
< = less than

ROUTE OF ADMINISTRATION

IH = inhalation
IM = intramuscular
IP = intraperitoneal
IS = intraspinal
IV = intravenous

PO = oral
R = rectal
SC = subcutaneous
SL = sublingual
TOP = topical application

BIOLOGICAL SPECIFICATION

ISu = in situ
IVt = in vitro
IVv = in vivo
sp = species

RBC = red blood cell (erythrocyte)
WBC = white blood cell (leukocyte)
♂ = male
♀ = female

1. DEVELOPMENT OF THE CIRCULATORY SYSTEM. VERTEBRATES

Part I: FROG

Values are principally for Rana pipiens or R. fusca. At a given stage, age and size can be expected to vary widely with differences in geographic strains and culture conditions. Stages designated for the embryo are adapted from Shumway [3], and those for the larva from Taylor and Kollros [5].

	Stage	Age	Size mm	Order of Development	Reference
	(A)	(B)	(C)	(D)	(E)
				Embryo[1]	
1	15			Heart rudiment lies within heart bulge.	1
2	16	72 hr	3	Pericardial cavity indicated by split in mesoderm.	1
3				Temporary ventral mesocardium.	
4	17	84 hr	3.5	Dorsal mesocardium.	1
5				Heart a straight tube.	
6				Truncus arteriosus branched	
7				Blood island within 1st aortic arch.	
8				Dorsal aorta.	
9	18	96 hr	4	Rudiments of vitelline veins	
10	19	118 hr	5	Heart S-shaped.	2
11				Truncus arteriosus connects to 1st aortic arch, and thus to dorsal aorta.	1,3
12				Blood islands in 2nd aortic arch, and numerous islands below posterior yolk mass.	
13				Blood in heart.	
14				Heart beat.	
15				Common cardinal veins and hepatic veins empty into sinus venosus.	
16	20	140 hr	6	Anterior lymph hearts.	
17				Pulmonary vein rudiments.	2
18	21	162 hr	7	Interatrial septum.	
19				Sino-atrial constriction.	1,2
20				Atriobulbar constriction.	
21				Circulation through aortic arches I and II.	
22				Formation of anterior cardinal veins and arteries of the brain.	
23				Suprabranchial aortas fuse to single dorsal aorta medial to pronephros.	
24	22	192 hr	8	A few blood cells weakly ellipsoidal--most, spherical.	
25				Trabeculae carnae in ventricle.	
26				Partitioning of heart complete.	1-3
27				Circulation in tail fin.	
28	23	216 hr	8-9	Atrioventricular constriction.	
29				Truncus arteriosus has thick endothelial cushions at level of its branching.	1
30				Blood cells ellipsoidal.	
31	25	284 hr	10-11	Truncus arteriosus divided by median septum.	
32				RBC free of yolk granules.	
33				Spleen rudiment.	1,2
				Larva[2]	
34	I	3 da	13	Lymphocytes appear in spleen.	4
35	III	11 da	17	Thoracic ducts.	2
36	XXI-XXV	76-88 da	63-25[3]	Reorganization of aortic arches at metamorphosis.	2

/1/ At 18°C /2/ At 20°C. /3/ Size upon completion of metamorphosis highly variable, ranging from 16-30 mm.

Contributor: Kollros, Jerry J.

References [1] Kopsch, F. 1952. Die Entwicklung des braunen Grasfrosches Rana fusca Roesel. Georg Thieme Verlag, Stuttgart. [2] Rugh, R. 1951. The frog: its reproduction and development. Blakiston, Philadelphia. [3] Shumway, W. 1940. Anat. Rec. 78:139. [4] Fabrizio, M., and H. A. Charipper. 1941. J. Morph. 68:179. [5] Taylor, A. C., and J. J. Kollros. 1946. Anat. Rec. 94:7.

Part II: CHICK

Time of origin is expressed in days or hours of incubation, or number of pairs of somites.

	Time of Origin (A)	Structure (B)	Site of Origin (C)	Page in Reference (D)
1	3-5 somites	Epimyocardium.[1]	Thickening of splanchnopleure of amniocardiac vesicles.	156, 158
2	3-5 somites and onward in later stages	Vascular system.	Initiated in blood islands at posterior margin of area opaca.	154
3	3-5 somites	Ventral aorta.[2]	Hemangioblasts continuous anteriorly with primordia of heart.	157, 158
4	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible] cardinal vein).	[illegible] and omphalomesenteric vein at level of somite 4.	[illegible]
8	20 somites	Pulmonary vein.	Proliferation of hemangioblasts from dorsal wall of sinus venosus at level of lung buds.	255, 257
9	50-55 hr	Interatrial septum.	Vault of atrium between openings of sinus venosus and pulmonary vein.	432
10	70 hr	Subcardinal vein.	Series of venous islands on median surface of mesonephros.	453
11	35 somites	Pulmonary artery.	Network of hemangioblasts extending caudally from ventral aorta.	253
12	3 da	Granulocytes.		257-260
13	3-4 da	Thrombocytes.		257-260
14		Endocardial cushions of atrioventricular canal.	Floor and roof of the atrioventricular canal.	433
15		Umbilical vein.	Capillary plexus in the somatopleure extending back from the duct of Cuvier.	255
16	4 da	Interventricular septum.	Along sulcus from bulboatrial angle towards apex of heart.	430
17		Subclavian artery.	Segmental artery of the 18th intersomitic space.	445
18	5 da	Neutrophils.		257-260
19		Mesenteric vein.	Dorsal mesentery, near level of dorsal pancreas.	450
20		Hepatic portal vein, definitive vessel.	Mesenteric vein in the dorsal mesentery.	450
21		Pelvic lymph sac.	Hemangioblasts from intersegmental veins of pelvic region.	462
22	5-6 da	Septum aorticopulmonale.	Truncus and bulbus arteriosus.	428, 429
23	6-7 da	Vertebral artery.	First 5 or 6 segmental arteries, and the plexus they form around the secondary sympathetic ganglia.	443
24		Thoracic duct of lymphatic system.	Intramesenchymal spaces along ventrolateral side of dorsal aorta.	463
25	7 da	Jugular lymph sac.	Fusion of lymphatic vessels near anterior cardinal vein.	463
26		Eosinophils.	Spleen (?).	257-260
27	14 da	Basophils.	Spleen (?).	257-260
28	17 da	Lymphocytes.	Spleen and other lymphatic areas.	257-260

/1/ Contractions begin at stage of 9 somites. /2/ Onset of function, with beginning of circulation at stage of 16 somites.

Contributor: Hamilton, Howard L.

Reference: Hamilton, H. L. 1952. Lillie's Development of the chick. Henry Holt, New York.

1. DEVELOPMENT OF THE CIRCULATORY SYSTEM VERTEBRATES (Continued)

Part III PIG

Stages adapted from Witschi [9]

	Stage	Age da	Size mm	Order of Development	Reference
	(A)	(B)	(C)	(D)	(E)
1	14	14-15	2.5	Pericardial cavity, endocardium, and epimyocardium.	1
2				Anlagen of blood vessels.	
3	15	15-16		Ventral aorta.	1
4				Fusion of paired cardiac tubes.	
5				Blood in yolk sac.	
6				Blood finally in heart and blood vessels.	
7	16	15-17		Truncus arteriosus, bulbus arteriosus, ventricle, atrium, sinus venosus.	1, 2
8				Septum primum.	1
9			4.15	1st pair of aortic arches.	3
10				Dorsal aorta.	
11			4.0	Omphalomesenteric arteries.	4
12				Allantoic arteries and veins.	
13				Subintestinal artery	
14				Arteries of pronephros.	
15				Posterior cardinal vein.	
16				Duct of Cuvier.	
17				Umbilical veins	
18	17	17	6.0-6.5	Longitudinal neural artery.	4
19				Lateral cardinal vein.	
20	18	16.5-18	3.8-4 5	2nd aortic arch.	1, 3
21				Endocardial cushions.	
22	19	16 5-17.5	3.6-4.57	3rd aortic arch.	1, 3
23				Interventricular septum.	
24	20	17 5	4 46-7 0	4th aortic arch.	1, 3, 4
25				Mesial cardinal vein.	
26				Venous valves.	
27	22		6 0	6th aortic arch.	3, 4
28				Primitive head vein.	
29	23	20	6.4	Foramen II in septum I	1
30	25	20	8.0-8 6	Septum II.	1, 3
31				External carotid.	
32	26	20-21	9 5-10.0	Bulbus dividing into aortic and pulmonary trunks.	1, 5, 6
33				Inferior vena cava.	
34				Spleen.	
35	27	21-22	11.0	Thymus	7
36	28	22	12 0-14.0	Pulmonary, subclavian, basilar, and vertebral arteries	1
37	30	28	20.7	Brachiocephalic and left common carotid arteries.	1
38	35	52	90.0	Tonsil.	8

Contributor Kemp, Norman E

References [1] Keibel, F. 1897. Normentafeln zur Entwicklungsgeschichte der Wirbelthiere. 1 Normentafel zur Entwicklungsgeschichte des Schweines (Sus scrofa domesticus). Gustav Fischer, Jena. [2] Patten, B M. 1948 Embryology of the pig Blakiston, New York [3] Heuser, C. H 1923. Contr Embryol. Carnegie Inst. 15 121 [4] Sabin, F R. 1917. Ibid. 6 61 [5] Davis, D M. 1910. Am. J. Anat. 10 461. [6] Holyoke, E. A. 1936 Anat Rec 65 333 [7] Badertscher, J. A. 1915. Am J. Anat 17.317 [8] Levin, P. M. 1930. Anat. Rec 45 189 [9] Witschi, E. 1956. The development of vertebrates. W. B Saunders, Philadelphia.

This table must be used with discretion because of certain discrepancies between embryological terminology and anatomical or functional characteristics, stages or events. The descriptions are consequently arbitrary, for many different authors. These defects have been obscured by conversion of descriptions into symbols in order to *not indicate time or age relationships, but are merely space accommodations for the numerical headings.* Letters primordium; B = loop formed, onset of coiling, C = completion of basic plan; D = differentiation; E = erythrocyte fetal stage); I = appearance of lymphoid cells; J = lymphocytes present in tissue; K = lengthwise subdivision, primordial; N = major channels formed; P = primitive nodules present; S = secondary follicles; T = twitch, markedly decreased; 2, 3, 4, 6 = aortic arch number.

	Structure	Streeter's Horizons[1]														
		VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII
	Blood forming loci															
1	Yolk sac	V	X					Y								
2	Chorion		V	(X)-	-Y--	-----	(X)			Z						
3	Liver									X						
4	Spleen															
5	Bone marrow															
6	Pericardial cavity	A		D										C		
	Heart															
7	Atrium			M												
8	Septum primum					K				L						
9	Septum secundum									K						
10	Ventricle			T	M				K			L				
11	Bulboventricular loop			B												
12	Atrioventricular valve						A							G		
13	*Semilunar valve*											A			G	
14	Conducting tissue								D							
	Blood vessels															
15	Truncus arteriosus									K	L					
16	Aortic arches			N	2		3, 4	6								
17	Aorta			A							C					
18	Pulmonary artery								A		C					
19	*Ductus arteriosus*							A								
	Lymphatic vessels															
20	Jugular region								A							
21	Retro-peritoneal region												A			
22	Cisterna chyli region												A			
23	Posterior iliac region												A			
	Lymph nodes[7]															
24	*Jugular region*															
25	Retro-peritoneal region															
26	Posterior iliac region															
	Lymphatic tissues															
27	Palatine tonsil														A	
28	Pharyngeal tonsil															
29	Lingual tonsil															
30	*Peyer's patches*															
31	Thymus						(A)---	------	------	-(A)			(F)[10]-	D[11]	V----	-----
32	Spleen								A							
	Crown-rump length, cm	0.1	0.15	0.23	0.3	0.4	0.5	0.65	0.85	1.1	1.36	1.65	2.05	2.35	2.45	2.75

/1/ Use of Streeter's horizons as units for the first seven weeks is an attempt to minimize discrepancies arising vessels have almost reached vertex. /4/ Lymph vessels have probably reached intestinal mucosa. /5/ Thoracic lymph nodes are found in various primitive conditions well after birth /8/ Secondary nodules present. /9/ Pit corpuscles. /13/ Malpighian bodies.

Contributors: (a) Böving, Bent G., (b) Clark, Eliot R., (c) Neill, Catherine A., (d) Kampmeier, Otto F.

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MAN

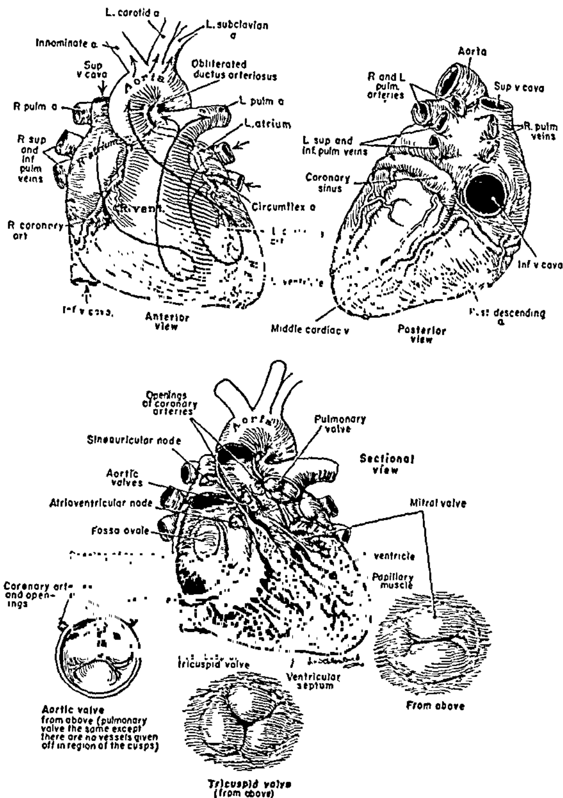
fact. *The changes* which constitute development are continuous but must be *described in discontinuous* units of time, have units which are unmeasurable, *unreliable, estimated,* omitted, qualified or used *in different* senses by emphasize essential *features* and reveal the quite regular sequence of events. *Differences* in width of columns do in parentheses and connected by dashes, are ranges. ⟶ indicates time spread. Abbreviations: A = anlage or formation. F = fusion or closure; G = growth completed. *H = humerus marrow formation begins* (defines onset of branching, or separation begun; L = lengthwise subdivision, branching, or separation completed; M = myocardium circulation *begins;* V = vascularization begins; X = hemopoiesis begins; Y = hemopoiesis maximal. Z = hemopoiesis

XXIII	8	9	10	12	14	16	18	20	24	28	32	36	38	After Birth	Reference	
															1-9	1
			(Z)-	----	----	----	-(Z)									2
																3
										Y	Z					4
						(E) X--	--Y--	--Z--	----	----	-(E)					5
	H														1-4	6
															1-4,10-17	7
																8
														L^2		9
																10
																11
																12
																13
					G											14
															1-4,18	15
																16
	(Fetus)												(Birth)			17
																18
													F			19
			G^3												6	20
				G^4												21
	G^5															22
			G^6													23
	AJ⟶		J					P⟶			G			S⟶	6,19-21	24
				A												25
	A⟶															26
					(I)---	-(I)			G^8						6,7,21-27	27
					AJ⟶											28
								AJ						G^9		29
(F)[10]	(I)--	-(I)	D[12]					(A)---	--(A)							30
							(E)---	----	----	----	-(E)			G^{13}⟶		31
2.75	3.0	4.0	5.0	6.1	8.7	11.6	14.2	16.4	18.6	22.8	26.5	30.2	34.1	36.2		32

Weeks after Fertilization (columns 8–38)

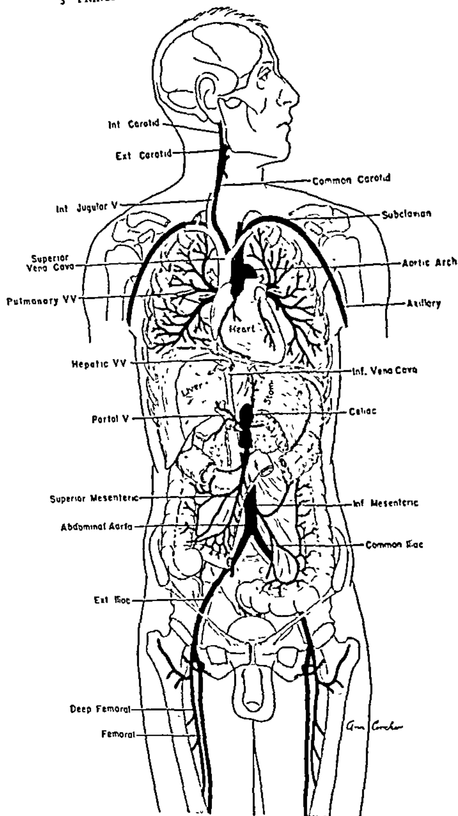
from uncertain age determination and individual rate of development. /2/ Six months after birth. /3/ Lymph *duct complete.* /6/ Lymph vessels have reached base of toes. /7/ The times given apply to the earliest nodes only. formation. /10/ Ectodermal and entodermal components fuse. /11/ Cortex-medulla differentiation. /12/ Hassall's

G. W., and H. M. Evans. 1926. Contr. Embryol. Carnegie Inst. 17.1. [3] Heuser, C. H. 1923. Ibid. 15 121. Florence R. 1912. In F. Keibel, and F. P. Mall, ed. Manual of human embryology. English ed. J. B. Lippincott, [8] Bloom, W., and G. W. Bartelmez. 1940. Am. J. Anat. 67:21. [9] Jägeroos, B. H. 1934. *Acta Soc. med.* 1937. J. Anat., Lond. 72.247. [12] Odgers, P. N. B. 1939. Ibid. 73 643. [13] Robb, J. S., C. T. Kaylor, and 1942. Am. J. Physiol. 13 146. [16] Marcell, M. P., and J. P. Exchaquet. 1938. Arch. mal. coeur 31:504. [17] Ebert, [19] Ehrich, W. 1929. Am. J. Anat. 43.385. [20] Kling, C. A. 1904. Arch. mikr. Anat. 63.575. [21] Jolly, J. F. P. Mall, ed. Manual of human embryology. English Ed. J. B. Lippincott, *Philadelphia. v. 2, p. 446.* [23] Lewis, Anat. 55.321. [26] Weller, G. L. 1933. Contr. Embryol. Carnegie Inst. 24.93. [27] Norris, E. H. 1938. Ibid.

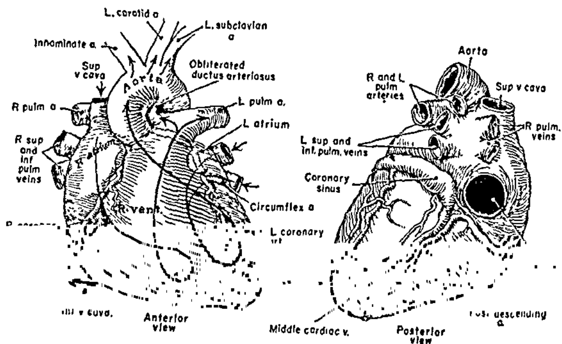


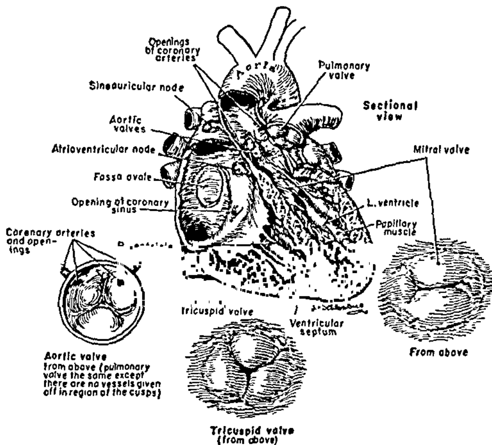
Reference Dorland's illustrated medical dictionary Ed 23 1957 W B Saunders, Philadelphia Plate XVII

3 PRINCIPAL ARTERIES AND PULMO...

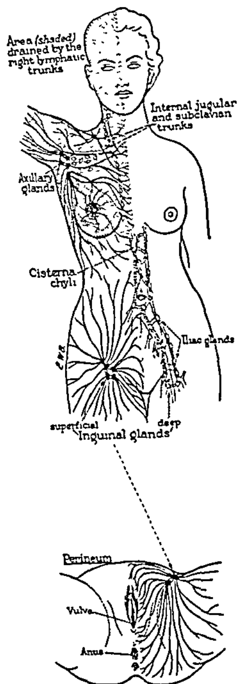


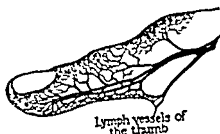
Reference Dorland's illustrated medical dictionary Ed 23 1957 W B Saunders, Philadelphia. Plate I

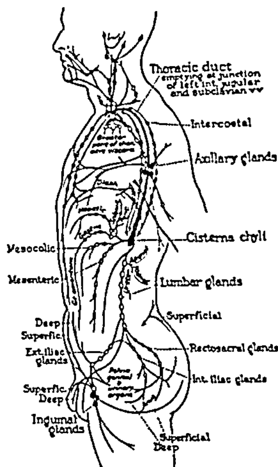




Reference. Dorland's illustrated medical dictionary Ed 23 1957 W B Saunders, Philadelphia Plate XVII.



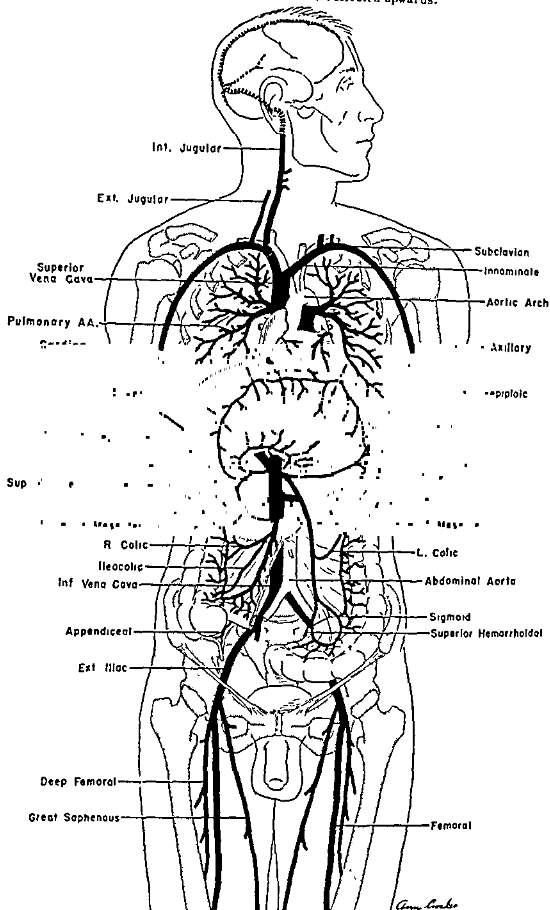




Reference Dorland's illustrated medical dictionary Ed 23 1957 W B Saunders, Philadelphia. Plate XXIV.

4. PRINCIPAL VEINS AND PULMONARY ARTERIES· MAN

The liver and stomach are shown reflected upwards.



Reference: Dorland's illustrated medical dictionary. Ed. 23. 1957. W. B. Saunders, Philadelphia. Plate XLVIII

ULATORY SYSTEM. VERTEBRATES

T

ct, see references 11-13

Reptiles[2] (F)	Birds (G)	Mammals (Ox) (H)	Mammals (Dog) (I)	Mammals (Man) (J)	
tly incorporated nto right atrium, and s distinct only internally[4]	Largely included in right atrium.	Incorporated into right atrium. Sino-atrial node, or "pacemaker," is a specialized tissue in atrial region (the latter was part of sinus in embryo).		Sinus venous completely incorporated in right atrium.[5] Sino-atrial node same as in ox and dog	1
pproximately same as in teleosts	Embryonic right sinal valve becomes valve of inferior vena cava.	Right valve of embryonic sinus becomes valve of inferior vena cava and of coronary sinus.		Vestige of embryonic sino-atrial junction found in adult right atrium.	2
ame as in frog, but interatrial septum contributes to valves dividing atrioventricular opening in two.	Complete interatrial septum. Extensive distribution of specialized conduction fibers	Complete interatrial septum. Histological characteristics of sino-atrial and atrioventricular nodal fibers unusually clear.	Complete interatrial septum. Sino-atrial node near opening of superior vena cava, atrioventricular node near opening of coronary sinus.	Complete interatrial septum except for small remnant of foramen ovale. Sino-atrial and atrioventricular nodes connected by typical cardiac fibers of right atrium	3
Turtle continuity of muscle as in teleosts, presence of "Purkinje-like" fibers controversial.[6] Alligator atrioventricular ring contains cartilage extending into base of right atrioventricular valve and similar valve of right aortic arch	Atrial and ventricular muscles separated by ring of connective tissue, except for atrioventricular bundles Right atrioventricular valve large and muscular, left valve is bicuspid.	Connective tissue of atrioventricular ring (annulus fibrosus) contains bone. Atrioventricular bundle is unusually distinct. Right atrioventricular valve usually tricuspid, left valve usually bicuspid	Atrioventricular valves same as in ox. Ring of connective tissue separates atrial and ventricular muscle, except for atrioventricular bundle of His.	Atrioventricular ring of dense connective tissue. Right atrioventricular valve is tricuspid, left valve is bicuspid. Atrioventricular bundle of His present from atrioventricular node to ventricles[7]	4
Turtle, snake, lizard: partially divided by incomplete septum Alligator complete ventricular septum containing cartilage.	Complete ventricular septum.	Complete septum. Histological characteristics of Purkinje (conduction) fibers distinct.	Complete ventricular septum.	Complete interventricular septum which is membranous in its uppermost reaches.	5
Conus incorporated in ventricle and in arterial trunks	Proximal portion incorporated in right ventricle, distal into right aortic and pulmonary trunks	Proximal portion incorporated in right ventricle, distal into left aortic and pulmonary trunks.			6
Turtle divided into right and left systemic and pulmonary trunks Alligator right and left systemics connected by foramen of	Divided into aortic and pulmonary trunks, semilunar valves at embryonic juncture of conus and truncus.				7

(e) Grodziński, Z., (f) DeGaris, Charles F., (g) Moog, Florence, (h) Ballard, W W

1956 Anat Rec 125 417 [3] Heinbecker, P., and G H Bishop. 1935 Am J Physiol. 114 212. [4] Hamilton J S 1953 Am J Physiol. 172 7 [6] Davies, F., and E. T B. Francis. 1946. Biol. Rev. Cambridge Philos. Soc anatomy. University of Chicago Press, Chicago [9] Patten, B M. 1946 Human embryology. Blakiston, Toronto Structure and development of vertebrates Macmillan, London. [12] Kingsley, J. S. 1917. Comparative anatom Blakiston, New York

Part I.

For a comprehensive review of the

	Component	Cyclostomes[1]	Elasmobranchs and Teleosts	Dipnoans	Amphibians
	(A)	(B)	(C)	(D)	(E)
1	Sinus venosus	Thin-walled, elongated sac, or tube, into which systemic veins open.	Smooth, thin-walled chamber into which systemic veins open. Cardiac muscle has high intrinsic contraction rate and acts as the "pacemaker."[3]		Salamander: thin-walled triangular shaped chamber, shifted toward right side. Frog: separate chamber, and relatively smaller.
2	Sino-atrial junction	Sino-atrial opening guarded by pair of valves.	Sino-atrial opening guarded by pair of valves. Cardiac muscle is continuous from sinus to atrium		Approximately same as in teleosts.
3	Atrium	Single, muscular sac. Atrium lateral to ventricle.	Thin, reticulate-walled chamber. No division into right and left sides; no pulmonary veins.	Partial septation. Pulmonary vein enters to left, and sinus venosus to right, of septum.	Salamander: incomplete septum partially dividing chamber bilaterally, with sinus venosus opening into right atrium and single pulmonary vein into left atrium. Frog: complete interatrial septum.
4	Atrioventricular junction	Atrioventricular channel connects both vesicles; two valves present.	Atrioventricular valve composed of two cusps. Cardiac muscle of atrium continuous with that of ventricle around entire circumference of the atrioventricular junction.	Fibrocartilaginous plug regulates blood flow.	Continuity of atrial and ventricular muscles, as in teleosts. Salamander: atrioventricular valve of two or four muscular thickenings. Frog: four valve cusps.
5	Ventricle	Thick-walled, muscular sac, with smooth internal surface.	Thick-walled chamber, network of muscular trabeculae. No division into right and left sides.	Septum present.	No ventricular septum.
6	Conus arteriosus	Absent, unless two valves may be regarded as remnants.	Variable in size; relatively large in cartilaginous fish, small in teleosts. Has semilunar valves.	Divided into dorsal and ventral channels.	Semilunar valves, also a "spiral valve" coursing lengthwise.
7	Truncus arteriosus[8]	Part bordering on ventricle enlarged to form bulbus arteriosus	Enlarged in teleosts which have reduced conus.	Divided into three paired channels.	Salamander: divided internally into right and left channels. Frog: divided both internally and externally into right and left channels.

/1/ Data from Favaro [1]. /2/ Data for alligator from White [2]. /3/ Although contraction is myogenic in origin, stimulation. /4/ Origin of beat in turtle heart is dependent on intrinsic ganglia [3]. /5/ Some authorities consider fibers are present in the turtle and in lower forms is supported by Robb [5], while the view that a specialized /7/ There are usually no muscular, atrioventricular connections other than the bundle of His in the adult [7]. arteriosus, or aortic sac [8-10].

Contributors: (a) Copenhaver, Wilfred M., (b) Andrew, Warren, (c) Monie, I. W., (d) White, Fred N.,

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5	Anterior cardinal veins	Petromyzon anterior cardinal veins unite to form common trunk and open into sinus venosus. Inferior jugular vein (ventral) present. Myxine left anterior cardinal vein (internal jugular) and inferior jugular vein (ventral) join sinus venosus. Right anterior cardinal vein opens into cor portale of liver.	Elasmobranchii anterior cardinal veins (internal jugulars) are sinus-like distentions. Inferior jugular veins open into duct of Cuvier. Teleostei two cardinal veins, mainly one internal jugular vein joining sinus venosus. Dipnoi two cardinal and two jugular veins.	Urodela two anterior cardinal veins (internal jugulars), two inferior jugular veins. Anura anterior cardinal veins (internal jugulars) and inferior jugular veins fuse into one short trunk on each side and enter sinus venosus by intermediation of anterior vena cava (cranial)	Sphenodon two anterior cardinal veins (internal jugular veins); inferior jugular veins (external) reduced and replaced by tracheal vein. These veins join subclavian vein to form anterior vena cava. Lacertilia. similar to conditions in Sphenodon	Two anterior venae cavae, each consisting of anterior cardinal vein, vertebral vein and subclavian vein. Right cardinal vein more prominent than left. Inferior jugular vein absent	Two anterior venae cavae (innominate veins of equal size), as in Rodentia and Insectivora. Each anterior vena cava consists of anterior cardinal, inferior jugular, and subclavian. Ungulata: Right vena cava more prominent than left because blood passes from left into right by anastomosis. Carnivora, Primates: Section of left vein, located between heart and anastomosis, disappears.
		Main Segmental Vessels					
6	Dorsal segmental vessels	In all embryos, three kinds of segmental vessels are present: dorsal, lateral, and ventral segmental arteries and veins. They persist at least partially in adults and give rise to some longitudinal as well as other important stems. Arteries and veins alternate in successive segments. Their dorsal tips join to form the longitudinal dorsal trunk, and may persist in adults. Tributaries of dorsal segmental vessels are ventral medullary arteries and veins, and muscular arteries and veins.			In each myoseptum, one artery and one vein are present. Their tributaries are ventral medullary and muscular arteries and veins. Ophidia: longitudinal dorsal vein is present.		
7	Dorsal rami		Deep pinneal arteries and veins are segmental vessels supplying dorsal fins				
8	Ventral rami		Segmental vessels run from the main longitudinal vessels (aorta, cardinal veins) in horizontal myoseptum and reach skin. Tributaries are muscular arteries and veins. Some become intercostal arteries and veins, surpassing main vessels in size. In region of paired fins and limbs, segmental vessels become subclavian and iliac arteries and veins.				
9	Lateral cutaneous vein[1]		Elasmobranchii, Dipnoi, Urodela, Apoda: lateral cutaneous vein in lateral line groove, below skin, from tail to region of forelimb. Originates from end tips of lateral segmental veins.	Anura. great and small cutaneous vein.	Lacertilia. lateral cutaneous vein probably present in all species.		
10	Abdominal vein[1]		Elasmobranchii: two lateral abdominal veins, one on each side of body wall. Extends from region of cloaca to shoulder girdle, where it merges into sinus venosus or into hepatic portal system.	Urodela, Anura: a single, median, ventral abdominal vein.	All reptiles: abdominal vein, double or single, connects renal portal with hepatic portal system.	Only anterior root of abdominal vein persists and is represented by umbilical vein in the embryo.	
11	Epigastric arteries & veins[1]	Myxine: netlike track.	Two distinct trunks running close to each other are present. These vessels are located on the inner surface of the abdominal wall between longitudinal abdominal and segmental trunk muscles; probably absent in birds.				

/1/ Longitudinal vessels originating from ventral rami of dorsal segmental vessels.

6. COMPARATIVE ANATOMY OF THE CIRCULATORY SYSTEM: VERTEBRATES (Continued)

Part II: BLOOD VESSELS

	Vessel (A)	Cyclostomes (B)	Fishes (C)	Amphibians (D)	Reptiles (E)	Birds (F)	Mammals (G)
	Main Longitudinal Vessels						
1	Aorta and caudal artery	Continuous vessels located ventral to the axial skeleton, extending from the region of the heart to the tip of the tail. Caudal artery enclosed in the hemal channel; aorta similarly enclosed in *Acipenser* (sturgeons) only.					
2	Aortic arches	Six, seven, or more epibranchial arteries.	Mainly 4-5 epibranchial arteries. *Dipnoi*: pulmonary arteries present.	One to four pair of aortic arches.	One pair of aortic arches.	Right aortic arch only.	Left aortic arch only.
3	Carotid arteries	*Petromyzon*: internal carotid artery (dorsal), external carotid artery (ventral). *Myxine*: internal and external carotid arteries	Internal carotid arteries.	Internal and external carotid arteries. *Anura*: carotid duct absent.	Internal and external carotid arteries originate from common carotids; many snakes possess only one common carotid. *Crocodilia*: carotid duct absent.	Internal and external carotids originate from common carotid arteries, which may be symmetrical, asymmetrical, fused, or one may be obliterated.	Various connections of internal and external carotids with aortic arch. innominate artery, common carotid artery, carotid trunk.
4	Posterior cardinal veins	In all embryos, two posterior cardinal veins are present, being continuous with the caudal vein. The formation of kidneys causes great changes in the distribution of the posterior cardinals (renal portal system).					
		Renal portal system absent. *Petromyzon*. same as in embryo. *Myxine*. same as in embryo, but right posterior cardinal vein much thinner than left.	*Elasmobranchii*. caudal vein empties into renal portal veins, hepatic veins empty into posterior cardinal veins, which are sinus-like distentions. *Teleostei*: posterior cardinals often asymmetrical but receive renal and hepatic veins, renal portal blood derived from caudal vein and/or segmental veins, caudal vein often leads directly to posterior cardinal. *Dipnoi*. caudal vein, renal portal veins, asymmetric posterior or cardinal vein, and a posterior vena cava.	Posterior cardinals rudimentary. Renal portal blood derived from iliac veins, and caudal vein in *Urodela*. Well-developed posterior vena cava drains kidneys.	*Lacertilia*: caudal vein empties into two renal portal veins. Two hepatic veins join posterior vena cava. *Crocodilia*: posterior vena cava emerges as single vessel from kidneys.	Rudimentary caudal and renal portal veins. Renal veins join femoral and internal iliac veins in kidney, which in turn join to form posterior vena cava. Posterior vena cava receives hepatic vein. No posterior cardinal veins persist.	No renal portal system. Posterior cardinals obliterated and replaced by supracardinal derivatives, the azygos and hemiazygos veins. Posterior vena cava is main trunk vein.

				Anural: subclavian arteries originate from aortic arch, brachial artery, and deep brachial artery. Other vessels same as in Urodela.	Chelonia: subclavian artery arises together with carotid artery from innominate artery. Brachial artery replaced by lateral brachial artery. Two arterial arches of hand, dorsal and volar.	interosseal artery, radial artery, ulnar artery, metacarpal and digital arteries	vessel in most mammals), ulnar artery (main vessel in Primates). Median artery, interosseal artery (main vessel in [illegible]), [illegible] dorsal and volar digital arteries.
17	Veins	Forelimbs absent.	Elasmobranchii: adradial veins, lateral and medial pterygial vein. Subclavian vein fuses with epigastric vein and enters duct of Cuvier. Teleostei: interradial veins, basal vein. Subclavian vein enters duct of Cuvier or posterior cardinal vein. Left subclavian joins abdominal vein and epigastric vein, right subclavian joins only epigastric vein (Salmo)	Urodela: digital veins, interosseal vein (main vessel), ulnar vein (ulnomarginal vein), radial vein (radiomarginal vein), brachial vein. Subclavian vein, together with lateral cutaneous vein, enters sinus venosus. Anura: digital veins, dorsal venous arch of hand, ulnar vein (ulnomarginal), radial vein (radiomarginal vein), interosseal vein. Brachial vein and great cutaneous vein unite to join subclavian vein which enters anterior vena cava (cranial). Deep brachial vein continues as subscapular vein which, together with internal jugular vein, forms brachiocephalic vein	Lacertilia: digital veins, dorsal venous arch of hand, radial vein (main vessel, marginal radial vein in embryo), ulnar vein, interosseal vein, brachial vein and lateral brachial vein. Lateral cutaneous vein empties into axillary vein. Subclavian vein enters internal jugular vein. Only one brachial vein in Lacerta and Alligator.	Metacarpal veins, basilic vein (ulnar, deep vein is main vessel). Ulnar vein, interosseal vein, radial vein [illegible] marginal vein), brachial vein, subclavian vein enters anterior vena cava.	[illegible] of these veins [illegible] digital veins, [illegible] veins, volar and dorsal venous arch, [illegible] vein (radial marginal vein), [illegible] vein (ulnar marginal vein), ulnar vein, radial vein, brachial vein, axillary vein, subclavian vein. [illegible]

Contributors (a) Grodziński, Z., (b) Monie, I. W., (c) DeGaris, Charles F., (d) Moog, Florence, (e) Ballard, W. W.

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6. COMPARATIVE ANATOMY OF THE CIRCULATORY SYSTEM. VERTEBRATES (Continued)

Part II: BLOOD VESSELS (Concluded)

	Vessel (A)	Cyclostomes (B)	Fishes (C)	Amphibians (D)	Reptiles (E)	Birds (F)	Mammals (G)
				Main Segmental Vessels (concluded)			
12	Lateral segmental vessels	Paired lateral vessels supply pronephros, mesonephros, and, when present, metanephros. Their number is much reduced in higher forms when forming renal and gonadal arteries.					
13	Ventral segmental vessels	In all embryos, ventral segmental vessels originate from the main longitudinal vessels (aorta, caudal artery, caudal vein); in trunk, only arteries (mesenteric arteries) originate from main longitudinal vessels, and in tail both arteries and veins (ventral segmental arteries and veins). The paired arteries frequently unite to form a single median vessel.					
14	Arteries	Myxine. mesenteric arteries (approximately 35 in number) distributed to intestine as segmental vessels. Petromyzon: only one artery persists as celio-mesenteric artery.	Elasmobranchii, Dipnoi. celiac artery, two or three mesenteric arteries. Teleostei mainly one celio-mesenteric artery.	Urodela: celiac artery, and about 13 mesenteric arteries almost segmental in arrangement, distributed to intestine (Siren). Segmental arteries fuse into complex vessels (Menobranchus, Cryptobranchus, Salamandra). Anura. only celiomesenteric artery.	Hatteria: gastric artery, celiac artery, common mesenteric artery (anterior), posterior mesenteric artery. Lacerta: gastric artery, celio-mesenteric artery, posterior mesenteric artery. Crocodilia: gastroesophageal artery, celio-mesenteric artery, mesenteric artery. Many arteries (mesenteric) reach intestine from the aorta (Boa).	Celiac artery, anterior mesenteric artery (superior), posterior mesenteric artery (inferior).	Celiac artery, anterior mesenteric artery (cranial or superior), posterior mesenteric artery (caudal or inferior).
15	Veins	Subintestinal vein, which gets some blood directly from caudal vein, develops with invasion of intestine by ventral segmental arteries. Subintestinal vein is prominent vessel in embryonic fish and amphibians, less significant in different reptiles and birds; remnants found in opossum. It parallels ventral border of intestinal tube and enters right omphalomesenteric vein. Subintestinal and parts of right and left omphalomesenteric veins form the hepatic portal vein.					
		Vitelline vein (omphalomesenteric) may participate in liver circulation.			Omphalomesenteric veins and umbilical vein participate in liver circulation.		
		Hepatic vein opens directly into heart.		Hepatic vein opens into posterior vena cava, subintestinal vein is incorporated into trunk of hepatic portal vein.			
		Petromyzon subintestinal vein well developed. Myxine. reduced.	Elasmobranchii, Dipnoi, many Teleostei: subintestinal vein well developed; absent in many Cyprinoids.				
				Vessels of the Forelimb			
16	Arteries	Forelimbs absent	Elasmobranchii: subclavian artery arises from median aorta. Lateral and medial pterygial artery, adradial arteries. Teleostei. subclavian artery originates from median aorta. Basal arteries, interradial arteries.	Urodela. subclavian artery arises from median aorta Brachial artery, interosseal artery (main vessel), radial artery (radiomarginal), ulnar artery (ulnomarginal). Dorsal arterial arch of hand, metacarpal arteries, digital arteries.	Lacertilia: both subclavian arteries arise from right aortic arch. Axillary artery, brachial artery, interosseal artery (main vessel), ulnar artery, radial artery and median artery. Metacarpal arteries, digital arteries.	Subclavian artery with carotid artery originates from right aortic arch (innominate artery). Axillary artery, brachial artery, ulnar artery (main vessel),	Right subclavian artery arises from left aortic arch, chiefly as innominate artery, left subclavian, direct from arch or truncus communis. Axillary artery, brachial artery, median artery (main

		sinus in liver region.					
5	Cisterna chyli in lumbar area			*Apoda*, Anura: absent. *Urodela*: present; extends to thoracic region.	Lacertilia, Chelonia, present. Crocodilia, Ophidia: absent.		Always present; great variation in shape and size.
6	Connections with veins	Petromyzon numerous connections with both posterior cardinal veins. Myxine: with anterior cardinal vein.	Elasmobranchii, with posterior cardinal vein at point where subclavian artery crosses. Teleostei with anterior cardinal veins.	Urodela: with anterior cardinal veins. Anura: with anterior lymph hearts.	With anterior cardinal veins.	With anterior cardinal veins.	In most mammals with left anterior cardinal vein, in some with right, in few with both.
7	Jugular lymphatic trunk	Petromyzon: seven peribranchial sinuses, each connected with anterior cardinal vein.	Elasmobranchii, two trunks connected with corresponding anterior cardinal veins. Teleostei: two sinus-like distended vessels connected with corresponding subvertebral trunks.	Urodela: two trunks connected with corresponding subvertebral trunks. Anura: two short trunks connecting head sinuses with anterior lymph hearts.	Lacertilia, two trunks connected with subvertebral trunks by way of jugular sinus. *Chelonia*: two trunks enter jugular cistern which connects both subvertebral trunks. Crocodilia two trunks enter corresponding anterior cardinal veins.	Each of two trunks join corresponding subvertebral trunk.	Irregular lymph vessels join anterior cardinal veins separately, or by way of subvertebral trunks.
8	Lateral longitudinal lymphatic trunks		Elasmobranchii, absent. Teleostei, Ganoidei: below skin in lateral line groove from base of tail fin to head; opens into some of head sinuses or directly into duct of Cuvier.	Apoda, Urodela: in lateral line groove from base of tail to head; opens into lymph hearts. Anura: in tadpoles: from base of tail to anterior lymph heart, disappears during metamorphosis.	Lacertilia: from tip of tail to forelimbs; caudal part enters lymph heart, thoracic part enters axillary sinus. Crocodilia: only caudal part present. Chelonia: thoracic part well developed. Ophidia: lateral trunk reaches maxillary sinus.		In adult, present only in tail; in embryos, transitory thoracic part observed.
9	Other longitudinal lymphatic trunks		Elasmobranchii, absent. Teleostei, Ganoidei: dorsal trunk unpaired, located in dorsal mid-line of tail and body, from base of tail fin to head; ventral trunk unpaired, located in ventral mid-line of tail and in middle of abdominal wall; spinal trunk dorsal to spinal cord.	Urodela: dorsal trunk unpaired, located in dorsal mid-line of tail and body; ventral trunk unpaired, located in ventral mid-line of tail; abdominal trunk paired in wall of abdomen. Anura: dorsal and ventral trunks only in fin of tadpoles.			

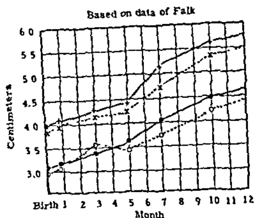
/1/ Cole [7] and Favaro [8] regard these sacs as venous hearts.

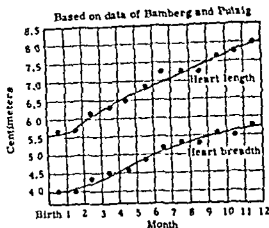
6. COMPARATIVE ANATOMY OF THE CIRCULATORY SYSTEM: VERTEBRATES (Continued)

Part III· LYMPHATICS

	Component	Cyclostomes	Fishes	Amphibians	Reptiles	Birds	Mammals
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Lymph hearts	Petromyzon: absent. Myxine: one pair of pulsating sacs located in tail.[1]	Elasmobranchii· absent. Teleostei: two elongated vesicles, joined by a channel and located at base of tail. Ganoidei: similar to Teleostei, but not pulsating vesicles.	Apoda: approximately 100 spherical vesicles in trunk and tail, beneath skin in lateral line groove. Urodela· 10-20 rounded vesicles on each side of trunk, located as in Apoda. Anura: one pair of anterior, and 1-4 pairs of posterior, hearts.	Only posterior hearts. Lacertilia: two ovoid vesicles attached to both ends of transverse process of first caudal vertebra. Ophidia: two elongated vesicles, each surrounded by bifurcated transverse processes of 4-5 caudal vertebrae. Dinosauria: volume of one heart of Apatosaurus, approximately 8000 ml; of Diplodocus, 20,000 ml. Chelonia, Crocodilia: spherical in shape.	In all embryos only one pair of posterior hearts, located in region between pelvis and femur; hearts persist in some adult birds (Struthio, Casuarius, Anser, Colymbus, Alca).	Absent even in embryos.
2	Other lymph sacs, and sinuses	Petromyzon: supralabial sinus, orbital sinus, ocular ring sinus, deep labial sinus. Myxine: three subcutaneous sacs underlie entire skin.	Elasmobranchii· absent. Teleostei: pectoral pinneal sinus, orbital sinus, cephalic sinus, occipital sinus, lateral sinus.	Urodela: orbital sinus, sinus lymphaticus cordis, axillary sinus in larvae only. Anura: in tadpoles: mandibular sinus, circumoral sinus, pericardial sinus, temporal sinus; in adults: several subcutaneous sacs.	Lacertilia: retrocardial sinus, axillary sinus, jugular sinus, tracheal sinus, thyroidal sinus. Ophidia: mandibular sinus Chelonia: jugular cistern. Crocodilia: absent.		Jugular and iliac lymph sacs in embryo only.
3	Lymph nodes				Chelonia: small nodes in lower eyelid.	Microscopically discernible nodes in walls of lymph vessels. Anseriformes: two cervico-thoracic and two lumbar lymph glands, macroscopically visible.	Many lymph nodes: approximately 60 in dog, 300 in cattle, 465 in man, 8000 in horse.
4	Subvertebral lymphatic trunks (thoracic duct)	Petromyzon: unpaired sinus-like trunk beneath aorta and cardinal veins. Myxine: two wide trunks located on both sides of aorta; fused into wide	Elasmobranchii, Ganoidei, Teleostei: two slender trunks located on both sides of aorta and caudal artery.	Apoda: one sinus-like extended trunk accompanies aorta. Urodela: one or two trunks. Anura: two trunks.	Lacertilia, Ophidia: sinus surrounds aorta. Chelonia: two trunks in tail, single in body cavity, and bifurcated anteriorly. Crocodilia: two slender trunks.	Two trunks located on both sides of aorta.	One or two trunks associated with aorta and caudal artery.

8. DIMENSIONAL GROWTH OF THE HEART DURING FIRST YEAR: MAN





-+- Heart length, ♂
-x- Heart length, ♀
-•- Heart breadth, ♂
-o- Heart breadth, ♀

Reference Scammon, R. E. 1927. Radiology 9 94 (Based on data of A. A. Falk. 1901. The growth of the heart in children according to age. Dissertation (in Russian). Also on data of K. Bamberg, and H. Putzig. 1919. Zschr. Kinderh. 20 195)

9. HEART, LINEAR DIMENSIONS: MAN

Values are in centimeters.

	Age	Male			Female		
		Width	Length	Thickness	Width	Length	Thickness
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Newborn	4.0	3.1	1.9	3.9	2.9	1.7
2	5-6 mo	4.9	3.9	2.6	4.7	3.8	2.6
3	1-2 yr	6.2	5.0	3.0	5.9	4.9	2.9
4	3-4 yr	6.6	5.5	3.3	6.2	5.4	3.1
5	5-6 yr	7.3	6.5	3.5	6.4	5.9	3.4
6	7-8 yr	7.6	7.0	3.5	7.3	6.2	3.2
7	9-10 yr	8.2	7.3	3.4	7.2	6.2	3.6
8	13-14 yr	8.2	7.8	3.7	8.3	7.8	3.8
9	Adult	10.7	9.7		9.9	9.3	

Reference Krogman, W M 1941 Tabulae biol., Berl. 20 664.

10. HEART, SURFACE DIMENSIONS MAN

Values are in centimeters.

	Age yr	No. of Subjects	Filled Heart	
			Circumference of Base	Distance from Base to Apex
	(A)	(B)	(C)	(D)
1	1.25-2.5	51	13.0	5.5
2	3-3.5	29	13.0	6.0
3	4-4.5	21	13.0	6.2
4	5-5.5	14	13.0	6.4
5	6-6.5	6	15.5	7.0
6	7-7.5	11	19.5	8.0
7	8-8.5	15	17.0	8.0
8	9-9.5	4	17.0	8.0
9	10-10.5	10	17.5	8.0
10	11-11.5	14	18.5	8.5
11	12-12.5	9	17.5	8.5
12	13-13.5	6	19.0	9.0
13	14-14.5	3	19.0	9.0

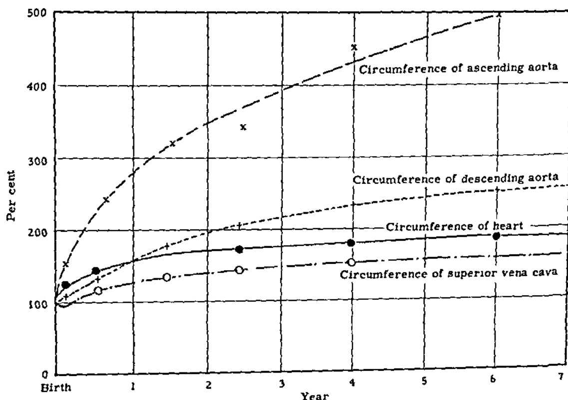
Reference. White House Conference on Child Health and Protection. 1933. Growth and development of the child. Century, New York Pt II

Contributor: Grodziński, Z.

References: [1] Allen, W. F. 1913-14. J. Micr. Sc., Lond. 59:part 2. [2] Allen, W. F. 1907. Proc. Washington Acad. Sc. v. 9. [3] Allen, W. F. 1908. Am. J. Anat. v. 8. [4] Baum, H. 1912. Das Lymphgefässsystem des Rhindes. Berlin. [5] Baum, H. 1928. Das Lymphgefässsystem des Pferdes. Berlin. [6] Clark, E. R., and E. L. Clark. 1920. Contr. Embryol. Carnegie Inst. 9·447. [7] Cole, F. J. Tr. R. Soc. Edinburgh, v. 54. [8] Favaro, G. 1905. Atti Ist. venet. sc. 65.195. [9] Glaser, G. 1933. Zschr. Anat. Entw. v. 100. [10] Grodziński, Z. 1932. Bull. internat. Acad. sc. Cracovie. [11] Grodziński, Z. 1929. Ibid. [12] Hoyer, H. 1934. Mém. internat. Acad. polon. sc., Cl. med. 1:205. [13] Hoyer, H. 1928. Bull. internat. Acad. sc. Cracovie p. 79. [14] Hoyer, H. 1905. Anat. Anz. 27:50. [15] Hoyer, H. 1908. Bull. internat. Acad. sc. Cracovie. p. 451. [16] Kampmeier, O. 1925-26. J. Morph. 41:95. [17] Kihara, R., and E. Naito. 1933. Fol. anat. jap 11:405. [18] Marcus, H. 1908. Morph. Jahrb. 38:590. [19] Mozejko, B. 1911. Anat Anz. 40:469. [20] Müller, J. 1941. Abh. K. Akad. Wiss., Berlin. [21] Müller, J. 1939. Ibid. [22] Panizza, B. 1833. Sopra il sistema linfatico dei rettili. Pavia. [23] Retzius, G. 1890. Biol. Untersuch., Stockh. 1·20. [24] Sabin, F. R. 1909. Am. J. Anat. 9.43. [25] Tretjakoff, D. 1927. Morph. Jahrb. 58·209. [26] Tretjakoff, D 1930. Ibid. v. 64. [27] Weidenreich, F. 1933. Lymphgefässsystem. In L. Bolk, ed. Handbuch der vergleichenden Anatomie der Wirbeltiere. Bd 6.

7. CIRCUMFERENTIAL GROWTH OF THE HEART, AORTA, AND SUPERIOR VENA CAVA: MAN

Growth computed as per cent of natal value.



Reference: Scammon, R. E. 1927. Radiology 9·97.

14. DIMENSIONS OF MAIN ARTERIAL TRUNKS: MAN

For information on the shapes of arterial segments, see reference 2. Values in parentheses are ranges, estimate "c" (cf. Introduction).

PART I UPPER ABDOMEN

Measurements made in anatomic dissection rooms on male cadavers injected with preserving *fluid and a colored* starch. Due to shrinkage upon fixation, width measurements of vessels may be smaller than those for living bodies. Width of left gastric, splenic, and hepatic *arteries* measured at point of origin from the celiac artery.

	Artery	No of Subjects	Age yr	Width[1] mm	Length mm
	(A)	(B)	(C)	(D)	(E)
1	Celiac trunk	47	61.4(34-81)	10.1(6-13)	24.8(11-35)[2]
2	Left gastric	48	61.4(34-81)	5.5(4-9)	
3	Right gastric	48	61.4(34-81)	1.7(1-4)	
4	Splenic	48	61.4(34-81)	8.5(6-14)	
5	Common hepatic trunk	48	61.4(34-81)	8.5(6-11)	
6	Hepatic to gastroduodenal	38	62.2(43-79)		31.1(20-50)
7	Hepatic to its divisions	7	54.4(34-74)		48.1(22-80)
	Terminal hepatic branches				
8	Right hepatic	43	60.8(34-81)	6.4(4-9)	
9	Left hepatic	44	61.2(34-81)	5.0(3-7)	
10	Middle hepatic	48	61.4(34-81)	3.6(2-6)	
	Aberrant hepatics				
11	*Accessory right hepatic from superior mesenteric*	7	59.8(43-74)	5.1(2-8)	80.0(70-90)
12	Replaced right hepatic from superior mesenteric	4	66.2(57-73)	7.0(6-8)	80.0(70-100)
13	Accessory left hepatic from left gastric	5	55.7(39-69)	4.4(4-5)	
14	Replaced left hepatic from left gastric	4	50.5(43-58)	4.8(4-5)	
15	Single cystic	36	59.2(34-81)	2.7(2-4)	17.7(2-30)
	Double cystic				
16	Superficial	12	66.2(58-74)	2.3(2-3)	22.2(10-33)
17	Deep	12	66.2(58-74)	2.4(2-4)	23.8(10-50)
18	Superior mesenteric	48	61.4(34-81)	11.2(8-14)	
19	Interval from celiac to superior mesenteric	48	61.4(34-81)		9.2(2-30)
20	Gastroduodenal	48	61.4(34-81)	5.3(4-7)	

/1/ External diameter measurement /2/ Length of celiac artery arbitrarily determined as the distance from its point of origin in the aorta to the point at which the celiac trunk branches into the hepatic and splenic arteries.

Contributor: Michels, Nicholas A.

References: [1] Michels, N. A. 1955. Blood supply and anatomy of the upper abdominal organs. J. B. Lippincott, Philadelphia. [2] Jeffords, J. V., and M. H. Knisely. 1956. Angiology, Balt. 7:105.

Part II. LOWER ABDOMEN

Measurements made on cadavers injected with latex.

	Artery	No of Subjects	Age yr	Width mm	Length mm
	(A)	(B)	(C)	(D)	(E)
1	Aorta	3	1(0.5-1.5)	7(6.5-8.0)	
2		29	(19-72)	14.4(9-18)	
3	Inferior mesenteric	3	1(0.5-1.5)	2.6(2.0-3.5)	58.6(50-60)
4		32	(19-72)	3.7(2.5-5.0)	120(77-170)
5	Interval from superior mesenteric to inferior mesenteric	3	1(0.5-1.5)		28.6(16-45)
6		24	(19-72)		53(35-70)
7	Interval from inferior mesenteric to [illegible]	3	1(0.5-1.5)		13(12-15)
8		28	(19-72)		31(15-45)
[illegible]	[illegible]	3	1(0.5-1.5)		16.3(15-18)
[illegible]	[illegible]	32	(19-72)		30.6(15-48)
[illegible]	[illegible]	8	Adults	2.9(2-4)	5(3-12)
12	Inferior common trunk (from *inferior* mesenteric)	8	7 adults, 1 child	2.7(2.0-3.5)	9.3(4-22)

Contributors: Gillot, Claude, and A. Delmas

Reference: La Société Anatomique de Paris. Unpublished

11. OSTIAL BREADTHS: MAN

Values are in centimeters and are for both sexes.

	Age yr	Tricuspid	Mitral	Pulmonary	Aortic
	(A)	(B)	(C)	(D)	(E)
1	Newborn	3.9	3.2	2.7	2.0
2	1-5	5.3	5.0	3.6	3.3
3	6-10	6.8	6.8	4.5	4.2
4	11-15	8.3	7.6	5.9	4.9
5	16-20	11.0	9.5	6.2	5.8

Reference: Krogman, W. M. 1941. Tabulae biol., Berl. 20:664.

12. GROWTH OF ARTERIAL LUMINA: MAN

Values are in square millimeters for cross-sectional areas.

	Age	No. of Subjects	Ascending Aorta	Common Carotid Artery		Subclavian Artery		Descending Thoracic Aorta	Smaller Arterial Branches	Sum of D-I[1]	Ratio of C:J[2]
				Right	Left	Right	Left				
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Newborn[3]	7	27.8	5.2	4.6	7.2	5.1	23.0	2.8	47.9	0.58
2	0-3 mo	31	42.8	5.7	5.9	7.3	6.1	24.6	4.3	53.9	0.79
3	3-12 mo	23	67.6	9.1	8.7	10.8	9.3	30.7	6.8	75.4	0.90
4	1-3 yr	41	93.9	12.2	12.6	15.8	13.1	44.4	9.4	107.5	0.87
5	3-7 yr	19	133.0	16.6	15.7	20 9	17.8	62.2	13.3	146.5	0.91
6	15-18 yr	25	221.7	23.6	22.5	32.0	27.1	107.6	22.2	235.0	0.94
7	20-30 yr	89	280.7	25.5	24.5	39.6	33.1	146.5	28.1	288.0	0.99
8	30-40 yr	60	314.9	28.0	25.6	41.7	40.3	235.0	31.5	325.1	0.97

/1/ Sum of the lumina of the common carotid artery, subclavian artery, descending thoracic aorta, and smaller branches. /2/ Ratio of the lumen of the ascending aorta to the sum of the lumina of the common carotid artery, subclavian artery, descending thoracic aorta, and smaller branches. /3/ Full-term stillborn.

Reference: White House Conference on Child Health and Protection. 1933. Growth and development of the child. Century, New York. Pt. II.

13. THICKNESS OF ARTERIAL WALLS: MAN

Values are in millimeters.

	Age yr	Pulmonary Artery	Aorta	Common Carotid
	(A)	(B)	(C)	(D)
1	1-2	0.79	0.83	0.55
2	3-4	0.91	1.14	0.59
3	5-6	0.66	1.23	0.60
4	7-8	0.72	1.36	0.89
5	9-10	1.16	1.39	0.79
6	11-13	1.07	1.49	0.90
7	14-16	1.01	1.41	0.90
8	17-19	1.12	1.58	0.90
9	20-22	1.12	1.58	0.93

Reference: Krogman, W M. 1941. Tabulae biol., Berl. 20:666.

17. HEART WEIGHT DURING FIRST YEAR: MAN

Values are for both sexes. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Age	No. of Observations	Body Length cm	Heart Weight g
	(A)	(B)	(C)	(D)
1	3.8(2-7) da	25	53.6	24.5
2	8.6(7-14) da	16	53.0	23.2
3	15.4(14-21) da	20	54.0	22.9
4	22.0(21-30) da	17	53.7	21.5
5	1.3(1-2) mo	6	58.1	30.0
6	3(2-4) mo	28	62.6	30.5
7	5(4-6) mo	14	66.4	31.6
8	7.5(6-9) mo	22	71.3	35.5
9	10.5(9-12) mo	14	79.5	45.0

Reference: White House Conference on Child Health and Protection. 1933. Growth and development of the child. Century, New York. Pt. II.

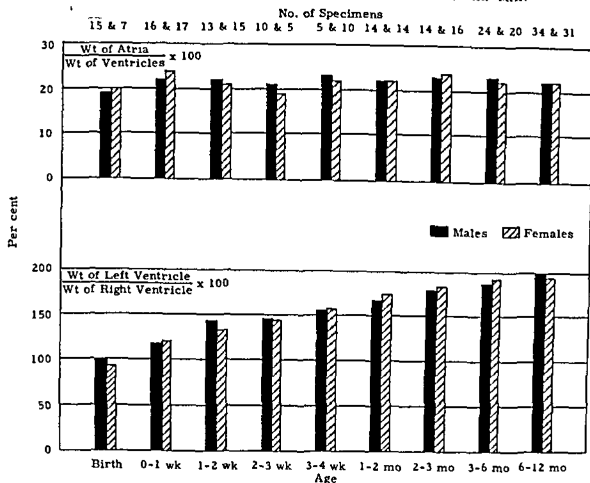
18. HEART WEIGHT AT VARIOUS AGES: MAN

	Age yr	Male		Female	
		No. of Specimens	Heart Weight g	No. of Specimens	Heart Weight g
	(A)	(B)	(C)	(D)	(E)
1	Birth	58	19	31	20
2	0.5-0.9	37	41	5	36
3	1-1.9	31	54	15	48
4	2-2.9	24	63	8	62
5	3-3.9	26	73	12	71
6	4-4.9	27	83	11	80
7	5-5.9	27	95	8	90
8	6-6.9	20	103	8	100
9	7-7.9	16	110	5	113
10	8-8.9	13	122	8	126
11	9-9.9	14	132	5	140
12	10-10.9	9	144	6	154
13	11-11.9	4	157	8	168
14	12-12.9	12	180	9	188
15	13-13.9	8	202	2	207
16	14-14.9	8	238	4	226
17	15-15.9	11	258	9	238
18	16-16.9	6	282	9	243
19	17-17.9	18	300	8	247
20	18-18.9	13	310	9	250
21	19-19.9	24	318	11	251
22	20-20.9	29	322	7	252
23	20-29		332		253
24	30-39		342		265
25	40-49		355		280
26	50-59		362		293
27	60-69		365		308
28	70-79		352		319

Contributor: Boyd, Edith

Reference: Boyd, E. 1952. An introduction to human biology and anatomy for first year medical students. Child Research Council, Denver.

15. ATRIO-VENTRICULAR WEIGHT RATIO DURING FIRST YEAR: MAN



Reference: Scammon, R. E. 1927. Radiology 9·95.

16. WEIGHT OF VENTRICLES: MAN

	Age	Right Ventricle g	Left Ventricle g	Left Ventricle % of Body Weight
	(A)	(B)	(C)	(D)
	Adapted from Müller			
1	Newborn	6.14	7.15	3.00
2	4-6 mo	6 55	12.35	2.97
3	7-12 mo	8.04	16.31	3.19
4	2 yr	12.42	22.00	2.92
5	3 yr	14.98	32.15	2.97
6	4-5 yr	16.24	34.20	3.04
7	6-10 yr	25.01	50.97	3.06
8	11-15 yr	34.00	67.10	2 45
9	16-20 yr	63.40	117.10	2.00
10	21-30 yr	70.80	125.10	2.44
	Adapted from Falk			
11	Newborn	6 54	8 14	2.70
12	5-6 mo	9 13	18.13	2 73
13	11-12 mo	12.47	24.48	2.50
14	1-2 yr	15.92	29.29	2.59
15	5-6 yr	23.24	44 98	2.50
16	7-8 yr	25.08	52.25	2 38
17	9-10 yr	27.70	57 74	2.23
18	12-13 yr	38.00	72.87	2.16
19	14-15 yr	49 56	96.74	2.34
20	16-17 yr	66.47	136.87	2.65

Reference: Krogman, W. M. 1941. Tabulae biol., Berl. 20 663. (Adapted from W. Müller 1883. Die Massenverhältnisse des menschlichen Körpers. Hamburg-Leipzig Also from A. A. Falk. 1938. In Dragendorff's Handbuch der Anatomie des Kindes. J. F. Bergmann, Munich. v. 2).

19. HEART WEIGHT: VERTEBRATES (Continued)

Part II. MAMMALS OTHER THAN MAN

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Primates					
1	Baboon (Papio cynocephalus)	1♂	19.51	79.94	0.41	Moto Umbo, Africa
2	Chimpanzee (Troglodytes niger)	1♂[1]	25.75	184 6	0.72	New York
3		1♂	52.16	250 0	0 48	Uganda, Africa
4		1♀	43.99	219 0	0.50	
5	Lemur (Galago senegalensis)	1♀	0.20	1.38	0.69	Maji Moto, Africa
6	Lemur, ring-tailed (Lemur catta)	1♀	1.73	8.2	0.47	New York
7	Monkey, gray (Cercopithecus mitis	1♀	1.22	6 56	0.54	Maji Moto, Africa
8	kibonotensis)	1♂	2.90	7.59	0.26	
9		1♂	4 55	35.32	0.78	
10	Monkey, howler, black (Alouatta palliata	10[2], ♂♀	0 67	3.9	0.58	Panama
11	inconsonons)	3[3], ♂♀	2.68	14.1	0 53	
12		28, ♂♀	6 17	20.67	0.34	
13	Monkey, howler, brown (A. palliata	2[2]	0.43	1.9	0.44	Panama
14	palliata)	5[3], ♂♀	1.21	8.0	0.66	
15		6, ♂♀	3.12	7.8	0.25	
16	Monkey, Humboldt (Lagothrix humboldti)	1♀	5.26	48.0	0.91	South America
17	Monkey, night (Aotus zonalis)	1[2]	0.212	1.5	0.71	Panama
18		18[3], ♂♀	1 93	7.65	0.39	
19	Monkey, rhesus (Macaca rhesus)	1♀[3]	1.39	5.3	0.38	Laboratory
20		7♀	3.63	12.2	0 34	
21		4♂	3.29	12.7	0 39	
22	Monkey, spider, black (Aotus dariensis)	2[2]	0.41	2.75	0.67	Panama
23		18[3], ♂♀	1.93	7.65	0.40	
24	Monkey, spider, red (Ateles geoffroyi)	19[3], ♂♀	1.03	4 49	0.44	Panama
25		11[3], ♂♀	2.81	14.52	0.52	
26		6[3], ♂♀	7.63	32.5	0.43	
27	Monkey, squirrel (Leontocebus geoffroyi)	13[2], ♂♀	0.191	1.34	0.71	Panama
28		19[3], ♂♀	0 475	3 02	0.64	
29		8, ♂♀	0.793	3 91	0.50	
30	Monkey, Sykes (Cercopithecus sp)	2♂	4.94	29.97	0.61	Maji Moto, Africa
31	Monkey, vervet (C. aethiops centralis)	2♂	4 19	19.98	0.48	Maji Moto, Africa
32		1♀[3]	1.23	6.56	0.53	
33	Monkey, whitefaced (Cebus capucinus	14, ♂♀	3.10	18.6	0.60	Panama
34	linnaeus)	6[3], ♂♀	1.32	7.53	0.57	
35		27[2], ♂♀	0.59	3.06	0.52	
36	Monkey, yellow titi (Saimiriorstedi	60, ♂♀	0 607	3.68	0.61	Panama
37	orstedii reinhardti)	2[2]	0.167	0 85	0.51	
38		2[3]	0.24	1.25	0.52	
	Carnivores					
39	Bear, grizzly (Ursus horribilis)	1♀	142 88	1132.5	0.79	Zoo
40	Bear, polar (Thalarctos maritimus)	1♂[4]	199.57	1161	0.58	Zoo
41		1♀	317.50	1220	0.38	
42	Cat, domestic (Felis domesticus)	1[3]	0 576	3.0	0.52	Panama
43		2, ♂♀	1.54	10.0	0.65	
44		2♂	2.89	12.38	0.43	Florida
45		5♂	3 78	16.82	0.44	Ohio
46		♂[5]	5.03	19.61	0.39	Florida
47	Cat, genet (Genetta tigrina suahelica)	2♂	1.30	7.51	0.58	Maji Moto, Africa
48		1♀	1.53	8 46	0.55	
49	Cat, wild (Felis ocreata)	1♀	2.70	5.87	0.22	Maji Moto, Africa
50	Cheetah (Acinonyx jubatus)	1♂	40.82	159	0.39	Zoo
51	Coati (Nasua narica panamaensis)	1	0.399	2.0	0.50	Panama
52		1♂	6.25	37.97	0.61	Guatemala
53	Coyote (Canis latrans)	1♀	8.51	72.71	0.85	Kansas
54	Dog (C. familiaris)	3♂	14.56	127	0.87	Maji Moto, Africa
55		2♀	12.47	120	0.96	
56	Dog, greyhound (C. familiaris)	1♂	24 49	308.8	1.26	Tennessee
57	Dog, Husky (C. familiaris)	2♂	31.75	297	0.94	Canada
58	Dog, mongrel (C. familiaris)	2♀	14 75	95.4	0.65	Florida
59		2♂	11.26	126.3	1.12	Ohio
60	Dog, collie-police (C. familiaris)	4♀	23.71	182.6	0.77	Ohio

/1/ Emaciated. /2/ Infant /3/ Juvenile /4/ Goiter. /5/ Feral.

19. HEART WEIGHT: VERTEBRATES

Values in column F, Part I, and column E, Parts II-V, are grams heart weight per 100 grams body weight.

Part I MAN

	Subjects	Age yr	Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat and Ancestry
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	American, Negro		♂	72.57	320	0.44	New York
2		24	♂	71.2	465	0.65	
3		41	♂	86.2	365	0.43	
4		45[1]	♂	73.0[1]	389[1]	0.53[1]	Louisiana and Ohio
5	American, white		♂	58.97	280	0.48	New York; Irish
6			♂	58.97	308	0.52	New York; Jewish
7			♂[2]	59.42	265	0.45	New York, Czechoslovakian
8			♂	61.24	250	0.41	New York
9			♂	63.50	310	0.49	
10			♂	65.77	270	0.41	New York; Irish
11			♂	70.30	320	0.46	New York; Italian
12			♂	70.30	310	0.44	New York; Jewish
13			♂	72.57	260	0.36	
14		22	♂	81.6	370	0.45	German
15		25	♂	78.5	331	0.42	Czechoslovakian
16		30	♂	65.8	340	0.52	Swedish
17		45	♂	50.0	325	0.65	New York; Scottish
18		54	♂	79.4	390	0.49	Polish
19		54	♂	81.6	400	0.49	
20		41	♂[3]	74.0	382	0.52	Ohio; Polish
21	Chinese		♂	83.89	555	0.66	Honolulu
22	Danish	13	♂	36.0	220	0.61	Denmark
23		28	♂	56 0	380	0.68	
24		39	♂	61.0	410	0.67	
25		44	♀	44.0	310	0.71	
26		47	♀	61.0	300	0.49	
27		50	♀	43.0	220	0.51	
28		55	♂	51.0	380	0.75	
29		55	♂	51.0	290	0.57	
30		60	♀	45.0	410	0.91	
31		65	♀	43.0	320	0.74	
32		68	♀	46.0	260	0.57	
33		68	♂	83.0	520	0.63	
34		78	♀	63.0	450	0.71	
35	Filipino	39	♂	43.09	200	0.46	Hawaii
36	Hawaiian	36-40	♂	95.0	430	0.45	Hawaii
37	Maya Quiche Indian	17	♂[4]	37.0	159	0.43	Guatemala
38		25	♂[5]	42.0	220	0.52	
39		28	♀[4]	45.8	225	0.49	
40		32	♂[6]	45.0	226	0.50	
41		32	♂[7]	49.9	240	0.48	
42		35	♂[8]	43.4	210	0.48	
43		45	♂[4]	36.3	155	0.43	

/1/ Mean value for 4 subjects. /2/ Goiter. /3/ Immigrant. /4/ Death from cachexia. /5/ Death from tuberculosis. /6/ Death from pneumonia (goiter). /7/ Death from double pneumonia. /8/ Death from septicemia (goiter).

Contributors: (a) Quiring, Daniel P., (b) Lowrance, E. W.

Reference: Quiring, D. P. 1950. Functional anatomy of the vertebrates. McGraw-Hill, New York. p. 528.

Part II. MAMMALS OTHER THAN MAN (Continued)

	Species	No and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Rodents (concluded)					
119	Hamster, golden (Cricetus cricetus)	2♀	0.129	0.60	0 47	Ohio
120		2♂	0 108	0.54	0.50	
121	Hare, African (Lepus capensis)	1♀	2.93	30	1.02	Maji Moto, Africa
122	Hare, arctic (L. arcticus arcticus)	2♂	1.90	28.45	1.50	Canada
123		2♂	2.64	28 87	1.09	
124	Lemming, brown (Lemmus trimucronatus)	4♀	0.029	0.43	1.48	Canada
125		1♂	0.048	0.60	1.25	
126	Lemming, rock (Dicrostonyx rubricatus richardsoni)	4♂	0.052	0.31	0.60	Canada
127		3♀[8]	0 055	0.38	0.69	
128	Mouse, African (Mastomys coucha microdon)	1♂	0 022	0.122	0 55	Maji Moto, Africa
129	Mouse, dormouse (Claviglis saturatus)	1♀[8]	0 022	0.113	0 52	Maji Moto, Africa
130		1♂	0.018	0.12	0.67	
131	Mouse, Guatemala (Peromyscus sp)[9]	14♂	0.012	0 098	0 81	Guatemala
132		2♀	0 018	0.11	0 61	
133		8♀[8]	0.02	0 15	0 75	
134	Mouse, jumping (Zapus hudsonicus)[9]	3♀	0.02	0.16	0.80	Ohio
135		1♂	0.015	0.13	0 87	
136	Mouse, meadow (Microtus drummondi)[9]	67♂	0 024	0.16	0.67	Canada
137		42♀	0 023	0.16	0 70	
138		4♀[8]	0.033	0.20	0 61	
139	Mouse, meadow (M. pennsylvanicus pennsylvanicus)[9]	42♀	0.025	0.197	0.79	Ohio
140		53♂	0.028	0.194	0.69	
141		10♀[8]	0.041	0.257	0 63	
142	Muskrat (Ondatra zibethica alba)	1♂	0 90	3.23	0 36	Canada
143	Porcupine (Erethizon dorsatus)	1♀	2.8	19.75	0.71	Maji Moto, Africa
144		2♀	2 7	14.4	0 53	New York
145		1♂	3 4	15.5	0 46	
146	Rabbit, Flemish giant (Lepus sp)	2♂	3 68	10 57	0.29	Ohio
147		22♀	2 59	9.23	0.36	
148	Rabbit, wild (Silvilagus gabbi messorius)	2	0.44	2.00	0.45	Panama
149	Rat, Norway (Rattus norvegicus)	1♀	0.20	0.73	0.37	Ohio
150		2♂	0.28	1.61	0.58	
151	Squirrel (Sciurus gerradi morulus)	1	0.29	2 00	0.69	Panama
152	Squirrel, ground (Citellus paryii paryii)	3♀	0.96	5.92	0 62	Canada
153		5♂	0.88	5 85	0 67	
154	Squirrel, red (Sciurus hudsonicus)	4♀	0.25	1.82	0.73	Canada
155		4♂	0.18	1.57	0 87	
156		1♂	0.17	2.13	1.25	Ohio
157		2♀	0.17	1.23	0 72	
158	Squirrel, red (S hudsonicus loquax)	1♂	0 18	1.51	0 84	Ohio
159		1♂[3]	0.063	0.545	0.87	
	Artiodactyla					
160	Bison, American (Bison bison)	1♂	54.88	361	0 66	Ohio
161	Buffalo (Syncerus caffer caffer)	1♀[8]	572	3050	0.53	Maji Moto, Africa
162		1♂	759	3628	0 48	
163	Bushbuck (Tragelaphus scriptus massaicus)	1♀	35 38	325	0.92	Maji Moto, Africa
164		1♂	53.07	350	0.66	Lake Manyara, Africa
165	Caribou, barren ground (Rangifer arcticus arcticus)	1♀	71.87	710	0.99	Canada
166		2♂	128.47	1066	0.85	
167		1♂	62.14	650	1.05	
168	Cattle (Bos taurus)	2[2]	20.75	248.7	1 20	Kentucky
169		1♀[2]	98.43	810 7	0.82	
170		1♀	378 75	2018	0.53	
171		71♀	506	1888	0.37	
172		18♂[10]	369	1533	0.42	
173	Cattle, Aberdeen angus (B. taurus)[11]	1♀	719	1950	0.27	
174	Cattle, Ayrshire (B taurus)[11]	44♀	491	1882	0.38	
175	Cattle, Guernsey (B taurus)[11]	62♀	450	1737	0 39	
176	Cattle, Hereford (B taurus)[11]	7♀	371	1143	0.31	

/2/ Infant /3/ Juvenile. /8/ Pregnant. /9/ Preserved weights /10/ Castrate. /11/ Data furnished by Swett, W. W , et al 1937 J. Agr. Res 55(4).

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
		Carnivores (concluded)				
61	Dog, police (Canis familiaris)	1♂[4]	38.42	261	0.68	Ohio
62	Fox, bat-eared (Otocyon megalotis)	1♀	3.34	24.65	0.74	Maji Moto, Africa
63	Fox, gray (Urocyon cineroargenteus scotti)	1♂	3.76	21.97	0.58	Florida
64	Fox, red (Vulpes fulva)	1♀	4.63	41.75	0.90	Canada
65	Hyena, spotted (Crocuta crocuta)	2	62.37	447	0.72	Maji Moto, Africa
66	Jaguar (Felis onca)	1♀	34.47	186	0.54	Zoo
67	Jackal (Thos mesomelas)	2♂[6]	2.85	21.33	0.75	Kitete Plains, Africa
68	Kinkajou (Potos flavus aztecus)	1♀	2.62	14.3	0.55	Guatemala
69	Leopard (Felis pardus)	1♂[4]	48	200	0.42	Zoo
70		1♀[2]	8.62	52	0.60	
71	Lion (F. leo)	1♀[4]	83.91[7]	455	0.54	Zoo
72		1♀	90.72[7]	327.3	0.36	Circus
73		1♀[2, 4]	50.9[7]	363.5	0.71	Zoo
74		1♀[4]	117.93	810	0.69	
75		1♂[4]	161.52	1614	1 00	
76		1♂[4]	117.57	713	0.60	
77		1♂[4]	94.86	743.2	0.78	
78		1♂[4]	126.08	1078	0.86	
79		1♂	195 4	1175	0.60	Maji Moto, Africa
80		1♂	186.36	860	0.46	
81	Lion, mountain (F. oregonensis)	1♂	28.79	184	0.64	New Mexico
82	Mongoose (Ichneumia albicauda)	1♂	4.40	28.30	0.64	Maji Moto, Africa
83	Raccoon (Procyon lotor pumilis)	1♀	2.23	19.73	0 89	Florida
84		1♀[4]	4.54	31.2	0.69	Zoo
85		1♂[4]	5.22	42.5	0.81	
86	Seal (Phoca richardi geronimensis)	1♂	107.3	1435	1.34	California
87	Seal, bearded (Erignathus barbatus)	1♀[3]	109.7	515	0.47	Canada
88		1♂	281	1245	0.44	
89	Seal, ringed (Phoca hispida)	3♂	39.76	281	0.71	Canada
90		2♀	39.68	302	0.76	
91	Serval (Felis capensis)	1♂	9.96	37.3	0.37	Maji Moto, Africa
92		2♀	5.82	28.45	0.54	
93	Tiger (F. tigris)	1♀[4]	160	432	0.27	Zoo
94		1♂	209	698	0.33	
95	Walrus (Odobenus rosmarus)	1♂[2]	79.38	731	0.92	Canada
96		1♀[2]	55.79	650	1.17	
97		1♂	667	4536	0.68	
98	Weasel, arctic (Mustela artica)	3♂	0.169	2.83	1.67	Canada
99		1♀	0.121	1 95	1.61	Ohio
100	Wolf, Russian (Canis lupus lupus)	1♂[4]	22.68	246	1.08	Zoo
101	Wolf, timber (C. lubilus)	1♂	29.94	315	1.05	Minnesota
		Rodents				
102	Agouti, brown (Dasyprocta punctata dariensis)	1[2]	1 40	10	0 71	Panama
103		3, ♂♀	2 06	9.2	0 45	
104		2, ♂♀	3 17	17.54	0 55	
105	Agouti, spotted (Cuniculus paca virgatus)	2[3], ♂♀	1 37	5.5	0.40	Panama
106		3, ♂♀	3 63	16.1	0.44	
107	Beaver (Castor canadensis)	1♂	4 18	16.57	0.40	Michigan
108		1♀	5.83	27	0.46	
109	Capybara (Hydrochoerus isthimius)	2, ♂♀	27.67	84 13	0.30	Panama
110		1[2]	7.09	24.18	0.34	
111		3♂[3]	14.96	55.06	0 37	
112	Chipmunk (Tamias striatus fisheri)	2♂	0 075	0.597	0.80	Ohio
113	Guinea pig (Cavia cutleri)	1♀[8]	0.351	1 72	0 49	Ohio
114		2♂	0.361	1.27	0.35	
115		2♀	0 324	1.31	0.40	
116		46♂, 56♀	0 215	1.29	0.60	
117		10♀	0.432	1 67	0.39	
118		10♂	0.456	1.86	0.41	

/2/ Infant. /3/ Juvenile. /4/ Goiter. /6/ Thyroid enlarged in one animal. /7/ Estimated. /8/ Pregnant.

Part II. MAMMALS OTHER THAN MAN (Continued)

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Perissodactyls (concluded)					
233	Horse, polo pony (*Equus caballus*)	1♀	380.75	3570	0.94	Ohio
234	Horse, saddle (*E. caballus*)	1♀[12]	39.50	381.5	0.93	Kentucky
235		2♀[3]	150.1	1156	0.77	
236		2♂	300.5	1658	0.55	
237		2♂[10]	335.68	2199	0.66	
238		1[10]	449	3495	0.78	Ohio
239	Horse, Shetland pony (*E. caballus*)	1♂[10]	242.67	2193	0.90	Kentucky
240		1♀	272.19	2506	0.92	Ohio
241		1♂	150.33	1375	0.91	
242	Horse, standardbred (*E. caballus*)	1♀[12]	31.75	402	1.27	Kentucky
243		1♂[2]	92.98	971	1.04	
244	Horse, thoroughbred (*E. caballus*)	5♂[12],5♀[12]	26.89	303.7	1.13	Kentucky
245		18♂[2]	52.45	565	1.08	
246		19♀[2]	54.32	606.4	1.12	
247		4♀[2]	116.77	1125	0.96	
248		8♂[3]	285.13	1999	0.70	
249		7♀	408.5	3237	0.79	
250		3♂	433.92	3488	0.80	
251		11♂[10]	445.76	3444	0.77	
252		10♀	441.36	3663	0.83	
253		5♂	485.31	4688	0.97	
254	Horse, western (*E. caballus*)	1♂[10]	426.38	3487	0.82	Ohio
255	Mule (*E. asinus*)	1♀	249.47	2144	0.86	Kentucky
256		1♀	444.52	3604	0.81	
257	Mule, Panama (*E. asinus*)	1♂[3]	42.64	397	0.93	Panama
258		4,♂♀	279.2	2048	0.73	
259	Rhinoceros (*Rhinoceros bicornis*)	1♂	764	4800	0.63	Maji Moto, Africa
260	Tapir (*Tapirella bairdii*)	1[3]	8.60	74	0.86	Panama
261		1♀	58.06	540	0.93	
262		1	14.26	121	0.85	
263	Zebra (*Equus quagga granti*)	1♂[12]	29.48	330	1.12	Zoo
264		1♀[2,4]	43.09	581	1.35	
265		1♀[2,4]	56.59	515	0.91	Maji Moto, Africa
266		1♂[4]	78.02	660	0.85	Zoo
267		2♂	254.99	1925	0.75	Maji Moto, Africa
268		1♀[8]	297.8	1970	0.66	
269		1♂	317.5	2231	0.70	Zoo
	Proboscidians, Hyracoideans, and Sirenians					
270	Elephant (*Loxodonta africana knochenhaueri*)	1♂	6654	26,080	0.39	Maji Moto, Africa
271	Hyrax (*Heterohyrax brucei*)	1♂	0.750	3.63	0.48	Lake Manyara, Africa
272	Manatee (*Trichechus manatus*)	1♂	426	1250	0.29	Florida
273		1♀	557.92	1247	0.22	
	Cetaceans					
274	Porpoise (*Phocaena phocaena*)	1♂	142.43	738	0.52	Florida
275	Whale, humpbacked (*Megaptera nodosa*)	1♂	37,195	214,000	0.58	California
276		2♂	40,370	187,000	0.46	
277	Whale, sperm (*Physeter catodon*)	1♂	39,009	126,000	0.32	California
278	Whale, beluga (*Delphinapterus leucas*)	2♀	303.23	1722	0.57	Canada
279		4♂	441.03	2434	0.55	
	Insectivores					
280	Mole (*Scalopus aquaticus*)	1♂	0.0396	0.272	0.69	Ohio
281	Shrew, short-tailed (*Blarina brevicauda*)	39♀	0.0163	0.1723	1.06	Ohio
282		29♀	0.0188	0.1922	1.02	
	Edentates					
283	Anteater (*Tamandua tetradactyla chiriquensis*)	1[3]	1.409	2.0	0.14	Panama
284		2,♂♀	3.692	18.0	0.49	
285	Armadillo (*Dasypus novemcinctus fenestratus*)	1[2],♂♀	0.471	2.3	0.49	Panama
286		4[3],♂♀	1.392	6.0	0.43	
287		1♂	3.701	14.7	0.40	
288		10♂	3.401	9.0	0.26	

/2/ Infant. /3/ Juvenile. /4/ Goiter. /8/ Pregnant. /10/ Castrate. /12/ Fetus.

Part II: MAMMALS OTHER THAN MAN (Continued)

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
	Artiodactyls (concluded)					
177	Cattle, Holstein (Bos taurus)[11]	200♀	574	2245	0.39	
178		6♂[2]	90	422	0.47	
179		3♂[3]	241	998	0.41	
180		5♂	552	1905	0.35	
181		5♂	888	3357	0.38	
182	Cattle, Jersey (B. taurus)[11]	218♀	413	1605	0.39	
183		3♂[2]	51.9	304	0.59	
184		5♂[3]	214	744	0.35	
185		2♂	367	1270	0.35	
186		10♂	597	2186	0.37	
187		213♂	412	1606	0.39	
188	Deer (Odocoileus chiriquensis)	2[3]	2.38	5.16	0.22	Panama
189		1♀	13.93	15.9	0.11	
190	Deer, Indian axis (Cervus axis)	1♂[4]	88.45	749	0.85	Zoo
191	Deer, white-tailed (Odocoileus virginianus)	1♂	65.22	632	0.97	Zoo
192	Dik-dik (Rhynchotragus kirki)	1♂	4.57	36.8	0.81	Maji Moto, Africa
193	Elk, American (Cervus canadensis)	1♂	13.61	131.1	0.96	Zoo
194	Gazelle, Thomson's (Gazella thomsoni)	1♀[2]	2.43	31.7	1.30	Maji Moto, Africa
195		2♂	24.37	245	1.01	
196	Giraffe (Giraffa camelopardalis tippelskirchi)	1♂	1220	4990	0.41	Maji Moto, Africa
197	Hartebeest, Coke's (Bublis cokei cokei)	1♂	134	875	0.65	Moto Umbo, Africa
198	Hippopotamus (Hippopotamus amphibius)	1♀[3]	543	1610	0.30	Maji Moto, Africa
199		1♀	1351	4536	0.34	
200	Impala (Aepyceros melampus)	2♂	37.86	270.05	0.71	Maji Moto, Africa
201		2♂	57.61	378	0.66	
202	Peccary, collared (Pecari angulatus bangsi)	1♂[4]	29	174	0.60	Zoo
203		1[2]	2.25	20	0.89	Panama
204		2	13.83	70.5	0.51	
205	Reedbuck (Redunca redunca tohi)	2♂	31.7	242	0.76	Lake Mangara, Africa
206	Sheep (Ovis aries)	2[12]	2.72	28.30	1.04	Kentucky
207		5♀[2]	8.55	85	0.99	
208		4♂	15.76	158.7	1.01	
209		7♀	52.1	276.7	0.53	
210		9♂	40.23	168	0.42	
211	Steinbok (Raphicerus campestris neumanni)	2♂	8.62	72.2	0.84	Maji Moto, Africa
212	Swine (Sus scrofa)	5[12], ♂♀	1.42	14.25	1.00	Kentucky
213		1♂[3]	4.76	52.1	1.09	
214		1♀[3]	13.15	124.5	0.95	
215		1♀	113.2	452	0.40	
216		53♂[10]	102.06	303.5	0.30	
217		36♀	102.06	324.39	0.32	
218	Warthog (Phacochoerus aethiopicus)	1♂	65.32	325	0.50	Maji Moto, Africa
219	Wildebeest (Connochaetes sp)	2♂	212.07	1313	0.62	Maji Moto, Africa
	Perissodactyls					
220	Burro (Equus asinus)	1♀	150.73	825	0.55	Guatemala
221		1♂[10]	199.58	1184	0.59	Kentucky
[illegible]	[illegible]	[illegible]	376.48	2607	0.69	Kentucky
		[illegible]	412.28	3587	0.87	Ohio
		[illegible]	122.98	850	0.69	Guatemala
			521.64	3260	0.62	Kentucky
		[illegible]	70.76	546	0.77	Kentucky
			184.16	1165	0.63	Kentucky
		[illegible]	362.87	1427	0.39	Illinois
			402.65	3648	0.91	Ohio
		[illegible], ♂♀	230.9	1843	0.80	Panama
		[illegible]	635.04	5600	0.88	Ohio
232		1♀	771.40	4700	0.61	

/2/ Infant. /3/ Juvenile. /4/ Goiter. /10/ Castrate. /11/ Data furnished by Swett, W. W., et al. 1937. J. Agr. Res. 55(4). /12/ Fetus.

Part III. BIRDS (Concluded)

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
39	Hawk, red-tailed (*Buteo borealis*)	1♀[1]	1.029	6.94	0.67	Ohio
40	Hawk, sharp-shinned (*Accipiter velox velox*)	1♀	0.520	3.70	0.71	Ohio
41	Hawk, sparrow (Falco sparverius sparverius)	1♂	0.112	1.12	1.00	Florida
42	Hornbill, ground (Bucorvus cafer)	1♂	3.25	56.61	1.74	Maji Moto, Africa
43	Hummingbird (Amazilia tzacatl tzacatl)	1♀	0.0048	0.1138	2.37	Guatemala
44	Loon, red-throated (Gavia stellata)	1♀	1.530	22.72	1.49	Canada
45		2♂	1.568	22.24	1.42	
46	Man-of-war (Fregata aquila)	1♂	1.405	16.59	1.18	Florida
47	Merganser, red-breasted (Mergus serrator)	1♀	0.770	11.01	1.43	Canada
48	Ostrich, Masai (Struthio camelus massaicus)	1♂	123	1205	0.98	Maji Moto, Africa
49	Owl, horned (Bubo virginianus virginianus)	1♂	1.177	8.60	0.73	Ohio
50	Partridge (Francolinus sephaena)	1♂	0.208	1.46	0.70	Maji Moto, Africa
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70	Swallow, barn (*Hirundo erythrogastra*)	1♂	0.0215	0.302	1.41	Ohio
71		2♀	0.021	0.283	1.35	
72	Teal, green-winged (Nettion carolinensis)	1♀	0.305	2.88	0.94	Canada
73	Vulture (Pseudogyps africanus)	1♀	5.27	37.85	0.72	Maji Moto, *Africa*

/1/ Juvenile

Contributor Quiring, Daniel P

Reference Quiring, D. P 1950. Functional anatomy of the vertebrates McGraw-Hill, New York. p. 528.

Part II: MAMMALS OTHER THAN MAN (Concluded)

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
		Edentates (concluded)				
289	Sloth, three-toed (*Bradypus griseus*	1[2]	0.676	3.0	0 44	Panama
290	*griseus*)	4[3], ♂♀	2.005	6.1	0.30	
		Marsupials				
291	*Opossum (Didelphis marsupialis*	8[3], ♂♀	0.666	3.4	0.51	Panama
292	*etensis)*	4, ♂♀	1.147	5.0	0.44	
293	Opossum, woolly (*Philander laniger*	1[3]	0.158	1.5	0.95	Panama
294	*pallidus*)	1	0.222	3.0	1.35	

/2/ Infant. /3/ Juvenile.

Contributors: (a) Quiring, Daniel P., (b) Lowrance, E. W.

Reference: Quiring, D. P. 1950. Functional anatomy of the vertebrates. McGraw-Hill, New York. p. 528.

Part III: BIRDS

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
1	Blackbird (*Quiscalus quiscula aeneus*)	1♂	0 082	1.159	1.41	Ohio
2	Bluebird (*Sialia sialis sialis*)	1♀	0.034	0.383	1.13	Ohio
3		1♂	0.029	0.493	1.70	
4	Bustard, greater (*Choriotis kori*	1♀	5.54	60.25	1.09	Athi Plain, Africa
5	*struthiunculus*)	1♂	10	97	0.97	
6	Bustard, lesser (*Haliaoetus bociter bociter*)	1♀	1.100	11.93	1.09	Maji Moto, Africa
7	Buzzard, steppe (*Buteo vulpinus vulpinus*)	1♂	0.560	4.58	0.82	Maji Moto, Africa
8	Buzzard, turkey (*Cathartes aura septentrionalis*)	1♂	0.495	10.24	2.07	Florida
9	Canary (*Serinus canarius*)	1♂	0.017	0.285	1.68	Ohio
10		1♀	0.015	0.133	0.89	
11	Catbird (*Dumetella carolinensis*)	1♂	0.033	0.327	0 99	Ohio
12	Cowbird (*Molothrus ater ater*)	1♀	0.066	1 06	1.61	Ohio
13	Crane, crested (*Balearica pavonina*)	1♀	4.071	41.21	1.01	Lake Manyara, Africa
14		1♂	4.825	32.37	0.68	
15	Crane, gray (*Grus canadensis*)	1♂	1.651	19.01	1.15	Florida
16	Crow (*Corvus brachyrhynchos*)	1♂	0.337	3.2	0.95	Ohio
17	Dovekie (*Alle alle*)	1♀	0.102	1.24	1.22	Florida
18		1♂	0.104	1.24	1.19	
19	Duck (*Nyroca affinis*)	1♂	1.041	13.4	1.29	Ohio
20	Duck, pintail (*Dafila acuta tzitzihoa*)	1♀	0 670	8.34	1.24	Canada
21	Eagle, fish (*Haliaetus vocifer vocifer*)	1♀	3.50	32.23	0.92	Maji Moto, Africa
22	Eagle, tawny (*Aquila rapax rapax*)	2♀	2.625	18.54	0.71	Maji Moto, Africa
23		2♂	2.438	14 17	0.58	
24	Egret, great white (*Casmerodius albus melanorhynchos*)	1♀	1.03	9.25	0.90	Maji Moto, Africa
25	Egret, yellow-billed (*Mesophyox intermedia brachyrhyncha*)	1♂	0.525	5 0	0 86	Maji Moto, Africa
26	Flamingo (*Phoeniconaias minor*)	3♀	1.483	14 68	0.99	Maji Moto, Africa
27		2♂	1 598	13.53	0.85	
28	Fowl, Leghorn (*Gallus gallus domesticus*)	10♀	0.4907	2.80	0.57	Ohio
29		10♂	0.5007	3 18	0.64	
30		16♀	0.6151	3.91	0.64	
31		8♂	0 7331	4 19	0 57	
32	Fowl, white Orpington (*G. gallus*	1♂	2.20	8.78	0.40	Ohio

0.96	Lake Manyara, Africa
0.88	Maji Moto, Africa
1.68	Canada
0.98	Florida
1.03	Florida
0.92	Florida

Part V: FISHES

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
1	Barracuda (Sphyraena barracuda)	1♀	4 803	7.78	0.16	Florida
2		1♂	5.990	12.25	0.20	
3		1♀	8 675	11.60	0.13	
4		1♂	9.150	60.31	0.66	
5		1♂	11.33	19 27	0.17	
6		1♀	12.69	16.05	0.13	
7	Bonita (Gymnosarda alleterata)	1♂	6 291	29.45	0.47	Florida
8	Carp (Cyprinus carpio)	4♂	1.0421	1.617	0.15	Ohio
9		2♀	1.061	1.554	0.15	
10		2♀	4.942	49 60	1.00	
11	Catfish (Clarias sp)	1♂	2 900	17.65	0.61	Maji Moto, Africa
12	Cisco (Argyrosomus artedi)	2♂	0.1621	1.592	0.98	Canada
13	Codfish (Gadus callarias)	1♀	10.6	161.4	1.52	Massachusetts
14		3♀	2.625	97.1	3.70	
15		3♂	2.518	96 2	3.82	
16	Eel, green moray (Gymnothorax funebris)	1	3.510	101.5	2 89	Florida
17	Grouper, black (Mycteroperca bonaci xanthastica)	1♂	2.712	11.66	0.43	Florida
18	Grunt, white (Haemulon plumieri)	1♂	0.30	3.55	1.18	Florida
19	Haddock (Melanogrammus aeglefinus)	6♀	3.275	132.6	4 05	North Atlantic Ocean
20	Hogfish (Lachnolaimus maximus)	1♂	0.480	0.452	0.09	Florida
21	Jack, common (Caranx hippos)	1♂	2.305	4 87	0.21	Florida
22	Jack, yellow (C. bartholomaei)	1♀	4.274	11.62	0.21	Florida
23		1♂	4 812	13.96	0.29	
24	Jewfish (Promicrops itaiara)	1♂	32.89	49.23	0.15	Florida
25	Kingfish (Scomberomorus regalis)	1♂	2.43	5.33	0.22	Florida
26	Mackerel (S maculatus)	2♀	1.457	2 93	0.20	Florida
27	Marlin, white (Makaira albida)	1♀	24.94	47.60	0.19	Florida
28	Muttonfish (Lutianus analis)	1♀	2.49	5.12	0.21	Florida
29	Palometa (Trachinotus glaucus)	1♀	8 504	24 83	0.29	Florida
30	Perch (Perca flavescens)	1♀	0.192	0.44	0.23	Lake Erie
31		6♂	0 167	0.3087	0 19	
32	Pike (Esox lucius)	4♂	0.3523	0.660	0.19	Lake Erie
33		2♀	0.3738	0 560	0 15	
34	Ray, electric (Torpedo torpedo)	1♂	0.345	0 22	0.06	Florida
35	Ray, sting (Dasybatis sabina)	2♂	17.58	47.58	0.27	Florida
36		1	2 675	6.83	0.26	
37	Sailfish (Istiophorus americanus)	1♀	25 20	49.15	0.20	Florida
38	Salmon (Salmo salar)	4♀	5.361	10.72	0.20	Coast of Maine
39		2♂	4 922	15.22	0.31	
40		1♂	3 93	6.42	0.16	
41		1♀	5.412	7.92	0.15	
42	Shad (Alosa ohiensis)	1♀	0 615	2.21	0.36	Ohio
43	Shark, sand (Carcharias littoralis)	1♀	35 38	41.6	0.12	Florida
44		1♂	35 83	40.14	0.11	
45		1♀[1]	123	115	0.09	

/1/ Pregnant.

19. HEART WEIGHT: VERTEBRATES (Continued)

Part IV: REPTILES AND AMPHIBIANS

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
1	Alligator (Alligator mississippiensis)	1♂[1]	0.105	1.39	1.32	
2		2♂[1]	0.351	1.62	0.46	Florida
3		1♀	52.4	137	0.26	Great Lakes Exposition
4		2♂	189	286.5	0.15	Florida
5	Crocodile (Crocodilus americanus)	1♀	134	134	1.00	Florida
6	Lizard (Lacerta viridis)	1♀	0.024	0 091	0.38	Maji Moto, Africa
7	Lizard, Gila monster (Heloderma suspectum)	1♀	0.514	4.17	0.81	Arizona
8	Lizard, horned toad (Phrynosoma cornutum)	2♂	0.025	0.126	0.50	Arizona
9	Lizard, iguana (*Iguana iguana*)	1♀	1.34	2.60	0.19	Guatemala
10	Lizard, iguana (Amblyrhynchus cristatus)[2]	1♀	4.19	21.51	0.51	Galapagos Islands
11	Snake, black (Coluber constrictor)	1♀	0.590	6.08	1.31	Ohio
12		1♂	0.286	0.96	0.34	Laboratory
13	Snake, boa imperator (Boa imperator)	1♀	1.829	5.64	0.31	Guatemala
14	Snake, garter (Thamnophis sirtalis)	1♀[3]	0.057	1.02	1.79	Ohio
15	Snake, python (Python molurus)	1♂	6.14	18.5	0.30	Enguruka, Africa
16	Snake, water moccasin (Agkistrodon piscivorus)	1♀	0.728	4.77	0.66	Florida
17	Turtle (Clemmys guttata)	1♂	0.185	0.57	0.31	Ohio
18		1♂	2.163	7.05	0.33	
19	Turtle (Chelydra serpentina)	1♀	5.125	13.43	0.26	Maji Moto, Africa
20	Turtle, green (Chelonia mydas)	1♀	68 04	180	0.26	Florida
21		1♂	114.3	435	0.38	
22	Turtle, leathernecked (Amyda forex)	1♀	3.253	16.0	0.49	Florida
23	Turtle, snapping (Macrochelys lacertina)	1♂	1.848	12.88	0 70	Ohio
24	Frog, bull (Rana catesbeiana)	1♂	0.339	1.37	0.40	North Carolina
25		6♂	0.5199	1.65	0.32	Louisiana

/1/ Infant. /2/ Preserved weights. /3/ Pregnant.

Contributor: Quiring, Daniel P.

Reference: Quiring, D. P. 1950. Functional anatomy of the vertebrates. McGraw-Hill, New York. p. 528.

21. CAPILLARY VASCULARITY OF MUSCLE: VERTEBRATES

"Capillary" counts from injected cross-section may not exclude other minute vessels (e.g., arterioles, venules).

Part I SKELETAL MUSCLE

For information on capillary capacity and surface area, see references 15-24. Abbreviations: A = asphyxiated, N = nourished, R = resting, S = starved, T = trained, U = untrained, V = vasodilated, W = working, SL = sea level, HA = high altitude (13,800 ft).

	Animal	Muscle	Physiologic Condition	Capillaries No./sq mm tissue[1] (cross-section)	Capillaries No./fiber	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
			Mammals			
1	Cat	Gastrocnemius	V	2341		1
2		Rectus femoris	V	2474		
3		Tibialis anterior	V	2214		
4	Dog, puppy	Gracilis	R	1690	0.7	2
5	Dog, adult	Gracilis	R	1050	0.6	2
6		Gracilis	W[2]	2010	1.2	
7		Gracilis	V	2580		
8		Semimembranosus	R	3240	0.6	
9		Semimembranosus	V	3900	1.6	
10		Semimembranosus	V	2630		3
11	Guinea pig	Abdominal wall	R	85		4
12		Abdominal wall	R	270		
13		Abdominal wall	V	1400		
14		Diaphragm	W[3]	2570		
15		Diaphragm	V, W[3]	3000		
16		Gastrocnemius	R	1136		5
17		Gastrocnemius	U	1378		6
18		Gastrocnemius	T	1924		
19		Gastrocnemius	W[2]	2000		5
20		Gastrocnemius	A	2600		
21		Gastrocnemius	V	2614		1
22		Gastrocnemius, external	SL	1542	2.5	7
23		Gastrocnemius, external	HA	2103	3.4	
24		Gastrocnemius, internal	SL	1621	2.5	
25		Gastrocnemius, internal	HA	2207	3.5	
26		Masseter	R	1927		5
27		Masseter	R	2840		3
28		Masseter	U	2873		6
29		Masseter	T	3064		
30		Masseter	W[2]	3200		
31		Masseter	A	3150		5
32		Pretracheal	V	3700		
33		Rectus femoris	V	3060		3
34		Rectus femoris	SL	1702	2.7	1
35		Rectus femoris	HA	2326	3.5	7
36		Thigh muscle, anterior (white)	SL	686	1.5	
37		Tibialis anterior	V	3501		
38		Vastus lateralis (white)	SL	740	1.4	1
39		Vastus lateralis (red)[4]	SL	1990	2.2	7
40		Vastus lateralis (red)[5]	SL	1897	3.0	
41		Vastus lateralis (red)	HA	2407	3.8	
42	Horse	Gastrocnemius	V	1350		
43	Mouse	Gastrocnemius	R	3060		3
44		Gastrocnemius	W[2]	3600		5
45		Gastrocnemius	A	4650		
46		Masseter	W[2]	4393		
47		Masseter	V, W[2]	5100		
48		Masseter	A	6800		
49	Rabbit	Adductor magnus (white)	V	1550	0.7	
50		Gastrocnemius	V	1344	1.6	8
51		Gluteal	U		0.5	9
52		Gluteal	T		1.2	10
53		Rectus femoris	V	1475	1.2	9
54		Semitendinosus (red)	V	790	1.2	8

/1/ Differences in counts during rest, work, and vasodilatation are now attributed to constriction of the meta-arteriole and to precapillary sphincter action [13, 14]. Because of parallel capillary pattern, counts are averages. /2/ Muscle or animal stimulated before injection. /3/ Classified as working (W), on basis of involuntary use. /4/ Young animal. /5/ Older animal.

19. HEART WEIGHT: VERTEBRATES (Concluded)

Part V: FISHES (Concluded)

	Species	No. and Sex	Body Weight kg	Heart Weight g	Heart Weight g/100 g	Habitat
	(A)	(B)	(C)	(D)	(E)	(F)
46	Shark, tiger (Galeocerdo tigrinis)	1♀	200	291.5	0.15	Florida
47	Sheepshead (Aplodinatus grunniens)	1♀	0.937	1.71	0.18	Ohio
48	Smelt (Osmerus mordax)	1	0.04766	1.29	2.71	Lake Erie
49	Snapper, vermilion (Rhomboplites aurorubens)	1♂	0.202	0.33	0.16	Florida
50	Trout, brown (Salmo trutta)	1♂	0.292	0.385	0.13	Ohio
51	Trout, northern (Cristivomer namaycush)	5♀	3.24	5.17	0.16	Canada
52		1♂	2.50	4.34	0.17	
53	Trout, rainbow (Salmo irideus)	4♀	0.2177	0.280	0.13	Ohio
54		2♂	0.2608	0.307	0.12	
55		1[2]	0.0428	0.095	0.22	
56		1♀[3]	0.1101	0.155	0.14	
57	Trout, salmon (S. gairdneri)	2♂	2.75	6.22	0.23	Canada
58	Trout, speckled (Salvelinus fontinalis)	1♀	0.255	0.99	0.39	Pennsylvania
59		1♂	0.2301	1.15	0.50	
60	Tuna (Thunus secundodorsalis)	1♂	5.21	31.22	0.60	Florida
61	Turbot (Balistes carolinensis)	1♂	0.295	0.364	0.12	Florida
62	Whitefish (Coregonus clupeiformis)	3♂, 3♀	0.7726	0.933	0.12	Lake Erie
63	Yellowtail (Ocyurus chrysurus)	1♀	0.255	0.37	0.15	Florida

/2/ Infant. /3/ Yearling

Contributor: Quiring, Daniel P.

Reference: Quiring, D. P. 1950. Functional anatomy of the vertebrates. McGraw-Hill, New York. p 528.

20. DENSITY, SURFACE, AND MAXIMUM DIFFUSION DISTANCE OF CAPILLARIES IN VARIOUS TISSUES: VERTEBRATES

	Tissue	Animal	Capillary Density no./sq mm	Capillary Surface sq cm/cu cm tissue	Maximum Diffusion Distance μ
	(A)	(B)	(C)	(D)	(E)
	Adipose				
1	Fat-rich	Rat	274	52	34
2	Fat-poor	Rat	1000	222	18
3	Brain, white matter	Man	300	57	33
4	Cerebellum	Mouse	1700	330	14
5	Cerebral cortex	Man	1000	190	18
6		Mouse	1250	240	16
7	Duodenum	Mouse	2400	460	11
8	Liver	Mouse	4200	800	9
9	Muscle	Dog	2600	590	11
10		Horse	1400	240	15
11		Frog	400	190	28
12	Heart	Mouse	5300	1000	8
13	Papillary	Man	5220	990	8
14	Pancreas	Guinea pig	1900	360	13
15	Renal cortex	Mouse	4500	850	8
16	Renal medulla	Mouse	7400	1400	7
17	Ventricle, left	Man	5730	1090	8
18	Right	Man	5680	1080	8
19	Ventricular septum	Man	4450	850	8

Reference: Kety, Seymour S. 1951. Pharm. Rev., Balt. 3.5.

21. CAPILLARY VASCULARITY OF MUSCLE: VERTEBRATES

"Capillary" counts from injected cross-section may not exclude other minute vessels (e.g., arterioles, venules).

Part I SKELETAL MUSCLE

For information on capillary capacity and surface area, see references 15-24. Abbreviations: A = asphyxiated, N = nourished, R = resting, S = starved, T = trained, U = untrained, V = vasodilated, W = working, SL = sea level, HA = high altitude (13,800 ft).

	Animal	Muscle	Physiologic Condition	Capillaries: No./sq mm tissue[1] (cross-section)	Capillaries: No./fiber	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
			Mammals			
1	Cat	Gastrocnemius	V	2341		1
2		Rectus femoris	V	2474		
3		Tibialis anterior	V	2214		
4	Dog, puppy	Gracilis	R	1690	0.7	2
5	Dog, adult	Gracilis	R	1050	0 6	2
6		Gracilis	W[2]	2010	1.2	
7		Gracilis	V	2580		
8		Semimembranosus	R	3240	0 6	
9		Semimembranosus	V	5900	1.6	
10		Semimembranosus	V	2630		3
11	Guinea pig	Abdominal wall	R	85		4
12		Abdominal wall	R	270		
13		Abdominal wall	V	1400		
14		Diaphragm	W[3]	2570		
15		Diaphragm	V, W[3]	3000		
16		Gastrocnemius	R	1136		5
17		Gastrocnemius	U	1378		6
18		Gastrocnemius	T	1924		
19		Gastrocnemius	W[2]	2000		5
20		Gastrocnemius	A	2600		
21		Gastrocnemius	V	2614		1
22		Gastrocnemius, external	SL	1542	2.5	7
23		Gastrocnemius, external	HA	2103	3.4	
24		Gastrocnemius, internal	SL	1621	2.5	
25		Gastrocnemius, internal	HA	2207	3.5	
26		Masseter	R	1927		5
27		Masseter	R	2840		3
28		Masseter	U	2873		6
29		Masseter	T	3064		
30		Masseter	W[2]	3200		5
31		Masseter	A	3150		
32		Pretracheal	V	3700		3
33		Rectus femoris	V	3060		1
34		Rectus femoris	SL	1702	2 7	7
35		Rectus femoris	HA	2326	3 5	
6		Thigh muscle, anterior (white)	SL	686	1.5	
7		Tibialis anterior	V	3501		1
8		Vastus lateralis (white)	SL	740	1 4	7
39		Vastus lateralis (red)[4]	SL	1990	2 2	
40		Vastus lateralis (red)[5]	SL	1897	3 0	
41		Vastus lateralis (red)	HA	2407	3 8	
42	Horse	Gastrocnemius	V	1350		3
43	Mouse	Gastrocnemius	R	3060		5
44		Gastrocnemius	W[2]	3600		
45		Gastrocnemius	A	4650		
46		Masseter	W[2]	4393		
47		Masseter	V, W[2]	5100		
48		Masseter	A	6800		
49	Rabbit	Adductor magnus (white)	V	1550	0 7	8
50		Gastrocnemius	V	1344	1 6	9
51		Gluteal	U		0.5	10
52		Gluteal	T		1.2	
53		Rectus femoris	V	1475	1.2	9
54		Semitendinosus (red)	V	790	1 2	8

... and vasodilatation are now attributed to constriction of the meta-
... 4]. Because of parallel capillary pattern, counts are averages.
... /3/ Classified as working (W), on basis of involuntary use.

Part I: SKELETAL MUSCLE (Concluded)

	Animal	Muscle	Physiologic Condition	Capillaries		Reference
				No./sq mm tissue[1] (cross-section)	No./fiber	
	(A)	(B)	(C)	(D)	(E)	(F)
	Mammals (concluded)					
55	Rabbit (concluded)	Semitendinosus (red)	V	1198	3.1	9
56	Rat	Rectus femoris	V	3573		1
57		Tibialis anterior	V	3402		
	Amphibians					
58	Frog (Rana esculenta)	Gastrocnemius	V	286	1.9	11
59		Obliquus oculi inferior	V	334	0.2	
60		Sartorius	V	309	1.3	
61		Submaxillarus	V	514	0.7	
62	Frog (R. temporaria)	Gastrocnemius	V	382	2.6	11
63		Gracilis	V	406	1.9	
64		Obliquus oculi inferior	V	393	0.2	
65		Sartorius	R	90		4
66		Sartorius	W[2]	325		
67		Sartorius	V	400		3
68		Sartorius	V	426	1.8	11
69		Submaxillarus	V	652	0.7	
70	Salamander (*Amblystoma mexicanum*)	Dorsalis trunci	V	133	1.0	11
71		*Extensor ileotibialis*	*V*	*264*	0.4	
72	Toad (Bufo calamita)	Gastrocnemius	V	444	1.6	11
73		Sartorius	N, V	520	1.2	
74		Sartorius	S, V	1021	1.6	
	Fishes					
75	Cod	Eye	W[3]	400		3
76	Hagfish (Myxine sp)	Axial		56		12
77	Trout	Eye	W[3]	276		12
78		Parietal	R	123		
79		Rectus lateralis	W[3]	400		

/1/ Differences in counts during rest, work, and vasodilatation are now attributed to constriction of the meta-arteriole and to precapillary sphincter action [13, 14]. Because of parallel capillary pattern, counts are averages. /2/ Muscle or animal stimulated before injection. /3/ Classified as working (W), on basis of involuntary use.

Contributors: (a) Fulton, George P., and Herbert J. Berman, (b) Shipley, Reginald A., (c) Burton, Alan C., (d) Lee, Richard E.

References: [1] Paff, G. H. 1930. Anat. Rec. 46:401. [2] Martin, E. G., E. C. Woolley, and M. Miller. 1931. Am. J. Physiol. 100:407. [3] Krogh, A. 1919. J. Physiol., Lond. 52:409. [4] Krogh, A. 1919. Ibid. 52:457. [5] Sjostrand, T. 1935. Skand. Arch. Physiol, Berl., Suppl. 71:1. [6] Petren, T., T. Sjostrand, and B. Sylven. 1936. Arbeitsphysiologie 9:376. [7] Valdivia, E. 1958. Am. J. Physiol. 194:585. [8] Stoel, G. 1925. Zschr. Zellforsch. 3:91. [9] Duyff, J. W., and H. D. Bouman. 1927. Ibid 5:596. [10] Vanotti, A., and M. Magiday. 1934. Arbeitsphysiologie 7:615. [11] Steudel, W. 1938. Zool. Jahrb. Abt. 2 Anat. Ontog. 65:63. [12] Gorkiewicz, G. 1947. Bull. internat. Acad. polon. sc., cl. med., Ser. B. II, p. 241. [13] Fulton, G. P., and B. R. Lutz. 1940. Science 92:223. [14] Chambers, R., and B. W. Zweifach. 1944. Am. J. Anat. 75:173. [15] Scarborough, R. A. 1930-31. Yale J. Biol. 3:63. [16] Dukes, H. H. 1942. The physiology of domestic animals. Cornell University Press, Ithaca. [17] Ponder, E. 1948. Hemolysis and related phenomena. Grune and Stratton, New York. [18] Prosser, C. L. 1950. Comparative animal physiology. W. B. Saunders, Philadelphia. [19] Krogh, A. 1929. *The anatomy and physiology of capillaries.* Yale University Press, New Haven. [20] Gibson, J. G., et al. 1946. J. Clin. Invest. 25:848. [21] Klein, J. R. 1945. Arch. Biochem., N. Y. 8:421. [22] Sharpe, L. M., G. G. Culbreth, and J. R. Klein. 1950. Proc. Soc. Exp. Biol., N. Y. 74:681. [23] Pappenheimber, J. R., E. M. Renkin, and L. M. Borrero. 1951. Am. J. Physiol. 167:13. [24] Dunn, J. R., Jr., S. Deavers, R. A. Huggins, and E. L. Smith. 1958. Ibid. 195:69.

21. CAPILLARY VASCULARITY OF MUSCLE: VERTEBRATES (Concluded)

Part II. SMOOTH MUSCLE

	Animal	Muscle Source	Capillaries/sq mm tissue[1] (cross-section)	Reference
	(A)	(B)	(C)	(D)
1	Dog	Circular layer of stomach	429	1
2		Longitudinal layer of stomach	432	
3		Longitudinal layer of intestine	264	2
4		Circular layer of intestine	356	

/1/ Calculated from total number of capillaries in gut smooth muscle/total volume of smooth muscle, assuming capillary length = 0.3 mm.

Contributors: (a) Fulton, George P., and Herbert J. Berman, (b) Shipley, Reginald A., (c) Burton, Alan C., (d) Lee, Richard E.

References: [1] Mall, F. P. 1889. Johns Hopkins Hosp. Rep. 1:1. [2] Mall, F. P. 1887. Abh. K. sächs Ges. Wiss. 24 151.

Part III: CARDIAC MUSCLE

For information on capillary capacity and surface area, see references 9-16.

	Animal	Heart Area and/or Condition	Capillaries: No./sq mm tissue[1] (cross-section)	Capillaries: No./fiber[2]	Reference
	(A)	(B)	(C)	(D)	(E)
1	Man, 6 mo fetus-16 yr		3744	0.3	1
2	25-77 yr		3343	0.8	
3	18-77 yr	Hypertrophied	2483	0.8	
4	49-71 yr	Atrophied	4613	0.6	
5	Cat[3]	Atrium	4800		2
6		Left ventricle	5728		
7		Right ventricle	5616		
8		Septum	5614		
9		Papillary muscle	4700		
10	Guinea pig		1970		3
11		Untrained	1948		3
12		Trained	2819		4
13			3407		5
14		Hypertrophied	2950		
15	Rabbit	Left ventricle	3420	1.1	6
16		Left ventricle, hypertrophied	2670	1.2	
17		Right ventricle	3310	1.0	
18		Right ventricle, hypertrophied	2740	1.2	
19		Papillary muscle	3230		
20	Snake (Tropidonotus natrix)	Inner	500		7
21		Peripheral	1000		8
22	Snake (Caretta caretta)	Inner	555		8
23		Peripheral	875		

/1/ Because of parallel capillary pattern, counts are averages. /2/ Number of capillaries divided by the number of separate groups of muscle substance present in a given cross-section. /3/ High counts may be due to shrinkage of heart tissue upon fixation. [6]

Contributors (a) Fulton, George P., and Herbert J Berman, (b) Shipley, Reginald A., (c) Burton, Alan C., (d) Lee, Richard E.

References: [1] Roberts, J. T., and J. T. Wearn. 1941. Am Heart J. 21 617. [2] Wearn, J. T. 1928. J. Exp. M. 47 273. [3] Petren, T., and B. Sylven. 1937. Morph. Jahrb. 79·200 [4] Petren, T., T. Sjostrand, and B. Sylven. 1936. Arbeitsphysiologie 9.376. [5] Rotta, A. 1943. Rev. argent. card 10.186. [6] Shipley, R. A., L. J. Shipley, and J. T Wearn. 1937. J. Exp. M. 65.29. [7] Stoel, G. 1925. Zschr. Zellforsch. 3 91. [8] Ludicke, M. 1939 Zool. Jahrb Abt. allg Zool. Physiol. Tiere. 59·463. [9] Ponder, E. 1948. Hemolysis and related phenomena Grune and Stratton, New York. [10] Scarborough, R. A. 1930-31. Yale J. Biol. 3 63. [11] Dukes, H. H. 1942. The physiology of domestic animals. Cornell University Press, Ithaca. [12] Prosser, C. L. 1950. Comparative animal physiology. W. B. Saunders, Philadelphia. [13] Krogh, A. 1929. The anatomy and physiology of capillaries. Yale University Press, New Haven. [14] Gibson, J. G., et al. 1946. J. Clin. Invest. 25.848. [15] Klein, J. R. 1945. Arch. Biochem. 8·421. [16] Sharpe, L. M., G. G. Culbreth, and J. R. Klein. 1950. Proc. Soc. Exp. Biol., N. Y. 74.681.

22. CHEMICAL COMPOSITION OF THE HEART: VERTEBRATES

Values for water are given in per cent of wet tissue, values for cholesterol and phospholipid in per cent of dry weight. All other values are in mg/100 g wet weight of tissue, unless otherwise indicated. Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I: MAN

	Chemical	Total Heart	Ventricle		Reference
			Left	Right	
	(A)	(B)	(C)	(D)	(E)
1	Water, %[1]	79.2	79.2	80.7	B, 1;C, D, 2
2		80.1	80.1(77.2-84.9)	80.0	B, C, 3, D, 4
3		79.7	77.8	80.6	B, 5;C, D, 6
4		78.9	80.8(79.7-81.9)	82.3(80.5-83.8)	B, 7, C, D, 8
5		79.0	79.3	80.3	B, 9;C, D, 10
6			79.0(75.8-80.4)	79.9(73.8-84.7)	11
7			78.9	79.2	12
8			79.0(78.4-79.1)		13
9			78.8(78.1-81.3)		14
10	Aluminum	0.21(0.11-0.29)			15
11	Bromine	0.21(0.065-0.325)			16
12		0			17-19
13	Calcium		6.4	7.3	10
14			7.2(4.7-10.8)	8.4(4.4-15.1)	11
15			6.9	7.6	12
16			8.0(5.0-10.0)		20
17	Chlorine[2]	124	120[3]	140	B, 21, C, D, 2
18			139(98-195)	182(136-222)	11
19			120	137	10
20			143(111-166)[4]		14
21	Chromium	0.01			22
22	Copper	0.77[5]			9
23		0.34			23
24		1.34[6]			24
25		3.65[7]	0.33(0.21-0.49)		B, 25;C, 20
26	Fluorine	0.46[6]			26
27	Iron	34.6[6]	11.8(4 2-21.3)[8]		B, 27, C, 3
28	Lead	0.06(0.05-0.08)[9]			28
29		0			29
30	Magnesium		21.1	18.4	10
31			18.7(10.4-26.1)	20.3(13.4-28.3)	11
32			20.1(15.6-23.2)	19.8(16.4-22.3)	12
33			16.4(8.9-22.4)[8]		3
34	Manganese	0.046			30
35		0.021			31, 32
36	Phosphorus, total	216(156-300)[4]	194(180-204)	160(140-187)	B, 14;C, D, 8
37			172	141	10
38			180(132-210)	147(126-172)	11
39			203	177	12
40			161(111-215)[8]		3
41			183.3		33
42	Potassium[10]	293[3]	314[3]	196	B, 7, C, D, 2
43			290.5[3]	285.5	6
44			285(251-305)	219(189-242)[3]	8
45			277	218	10
46			269(184-322)	206(146-240)	11
47			311	255	12
48			325(270-420)[4]	261[3]	C, 14;D, 4
49	Silicon	50[6]			34
50	Sodium[11]	109[3]	90 5[3]	112	B, 7, C, D, 2
51			99(83-132)	126(75-197)	11
52			92	107	12
53			114(84-142)[4]		14
54	Zinc	10[7]			24
55		(1.3-1 6)[9]			35

/1/ Ventricle apex, 79.4, base, 78.9. Right atrium, 81.2. Septum, 79.2. [2] /2/ Ventricle apex, 120, base, 120. Right atrium, 150. Septum, 120. [2] /3/ Recalculated from g/100 g wet weight. /4/ Recalculated from mEq/100 g wet weight. /5/ Recalculated from mg/kg dry weight. /6/ mg/100 g dry weight. /7/ Recalculated from mg/kg dry weight to mg/100 g dry weight. /8/ Recalculated from g of the metallic oxides/100 g dry weight to mg of the element/100 g wet weight. /9/ Recalculated from mg/kg wet weight. /10/ Ventricle apex, 311, base, 316 Right atrium, 139. Septum, 309. [2] /11/ Ventricle apex, 89, base, 92. Right atrium, 120. Septum, 94. [2]

22. CHEMICAL COMPOSITION OF THE HEART: VERTEBRATES (Continued)

Part I. MAN (Concluded)

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Reference
	(A)	(B)	(C)	(D)	(E)
56	Cholesterol, total, %		0.70		36
57	Collagen		910(600-1220)[3]	1580(1220-2000)[3]	37
58			960(610-1350)[3]		38
59	Creatine	202(117-262)	203(186-218)	165(154-185)	B,1;C,D,8
60		175(145-250)	208	149	B,5,C,D,39
61			220	156	40
62		(170-180)[12]	211(150-300)	148(100-250)	B,41;C,D,42
63			175	173	C,43,D,44
64			160(38-295)	114.5(38-230)	C,45,D,46
65			(220-285)		47
66	Phospholipid, %		7.00[13]		36

/3/ Recalculated from g/100 g wet weight. /12/ Recalculated from mg/g wet weight. /13/ Recalculated.

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Part II. CARNIVORES

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Atrium Left	Atrium Right	Septum	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
			Cat					
1	Water, %	80.8[1]	76.9					B,1,C,2
2		80.4[1]	77.7[1]	77.4[1]				B,3,4,C,D,5
3		78.7[1]						6
4	Chlorine	145[2]	125[2]					B,7,C,2
5		140.9[3]						1
6		133[3]						3,4
7		121[3]						6

/1/ Recalculated from g/100 g dry weight to per cent of wet tissue. /2/ Recalculated from mM/kg wet weight. /3/ Recalculated from mM/100 g dry weight

Part II: CARNIVORES (Continued)

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Atrium Left	Atrium Right	Septum	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Cat (concluded)							
8	Copper	1.44[4]						8
9	Lead	0.15						9
10	Nitrogen	2765[5]						3,4
11	Phosphorus, total	207[3]						1
12		206.5[3]						3,4
13	Potassium	301[3]	309.1[2]	310.6[2]				B,1;C,D,5
14		307.4[3]	240[2]					B,3,4,C,2
15		330[3]						6
16		366[3]						10
17	Sodium	94[3]	94[2]					B,6;C,2
18		110[3]						3,4
19		111.3[3]						1
20	Cholesterol, total, %		0.44(0.34-0.50)					11
21	Collagen	1193[1]						6
22	Creatine	267 (221-333)						12
23	Glycogen	476						13
24	Phospholipid, %		5.72[6]					11
	Dog							
25	Water, %	80.6	77.4	77.1	74.9	74.6		B,1;C-F,14
26		77.1	78.6	78.9			78.2	B,15,C,D,G,16
27			78.3	78.8			78.26	17
28		80.6[1]	78.3[1]					B,3;C,18
29			77.3	77.6				19
30			78.8					20
31			78.5					21
32			78.3					22
33			77.3					23
34	Aluminum	0.184 (0-0.608)						24
35		0.11 (0.02-0.17)						25
36		0.22						26
37	Bromine	0.19[7]						27
38		0.16						28
39		(0.55-0.63)						29
40	Calcium	75[4]	18.3	22.7				B,30;C,D,31
41			5.1[8]	5.3[8]	8.2[8]	8.4[8]		14
42			9.3					20
43	Chlorine	115[3]	70.5[8]	70.8[8]	72.7[8]	70.1[8]		B,1;C-F,14
44		119	90.2[2]	94.4[2]			83.8[2]	B,15,C,D,G,16
45		136	85.2[2]	88.4[2]			82.7[2]	B,28;C,D,G,17
46		112[3]	104.8[3]					B,3,C,18
47			108[2]					21
48			103[2]					22
49	Iron		0.27[9]	0.27[9]	0.19[9]	0.19[9]		14
50	Magnesium		21.6[8]	21.1[8]	13.9[8]	13.8[8]		14
51			22.7[10]					18
52	Manganese	0.021						32
53	Nitrogen, total	2852[7]	2960[7]	2900[7]	2480[7]	2360[7]		B,3,C-F,14
54	Phosphorus	216.5[3]	285	5.82[9]	4.64[9]	4.57[9]		B,1;C,20;D-F,14
55			767[4]	708[4]				31
56			223	205[11]			216	33
57	Potassium	326.9[3]	247[8]	248[8]	151[8]	136[8]		B,1;C-F,14
58			345[2]	375[2]			363[2]	16

/1/ Recalculated from g/100 g dry weight to per cent of wet tissue. /2/ Recalculated from mM/kg wet weight. /3/ Recalculated from mM/100 g dry weight. /4/ mg/100 g dry weight. /5/ Recalculated from g/100 g dry weight. /6/ Recalculated. /7/ Recalculated from g/100 g wet weight. /8/ Recalculated from mEq/kg dry weight. /9/ mEq/100 g wet weight. /10/ Recalculated from mEq/100 g dry weight to mg/100 g dry weight. /11/ Total

Part II· CARNIVORES (Continued)

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Atrium Left	Atrium Right	Septum	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Dog (concluded)							
59	Potassium (concluded)		333[2]	363[2]			354[2]	17
60		327.7[3]	294[3]					18
61			321[7]	362[7]				19
62			344					20
63			301[2]					21
64			319[2]					22
65			296[2]					23
66	Silicon	4[4]						34
67	Sodium	87.4[3]	133[8]	133[8]	69.9[8]	56.4[8]		B,1,C-F,14
68			71.5[2]	75.4[2]			70.2[2]	16
69			71.1[2]	75.0[2]			73.1[2]	17
70		86.0[3]	89.7[3]					B,3,C,18
71			75.4[2]					21
72			81.1[2]					22
73	Zinc	2.01					0.4	B,35,G,36
74	Cholesterol, total, %		0 61(0.49-0.90)					11
75	Collagen		415[12]	449[12]			407[12]	33
76				1380 (960-1890)[7]			1050 (770-1320)[7]	37
77	Creatine	287 (210-327)	289	268			282	B,12,C,D,G,33
78		243 (221-257)						38
79			331					18
80	Glycogen		603 (386-973)[13]	799 (374-1168)[13]	690 (451-1004)[13]	501 (308-609)[13]	612 (423-961)[13]	39
81		440 (270-570)[7]	573 (427-680)[7]	609 (386-737)[7]				B,40,C,D,41
82		385[7]	547[7]			534[7]		B,42,C,G,43
83	Phospholipid, %		8.54[6]					11

/2/ Recalculated from mM/kg wet weight. /3/ Recalculated from mM/100 g dry weight. /4/ mg/100 g dry weight. /6/ Recalculated. /7/ Recalculated from g/100 g wet weight. /8/ Recalculated from mEq/kg dry weight. /12/ mg collagen nitrogen/100 g wet tissue. /13/ Recalculated from mg glucose/g wet weight to mg glycogen/100 g wet weight

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Part III. RODENTS

	Chemical (A)	Total Heart (B)	Ventricle: Left (C)	Ventricle: Right (D)	Reference (E)
	Guinea Pig				
1	Calcium	6.8			1
2	Copper	2.12[1]			2
3	Magnesium	8.9			1
4	Manganese	0.021			3
5	Potassium	278			1
6	Sodium	133			1
7	Cholesterol, total, %		0.44(0.31-0.53)		4
8	Collagen	1028[2]			5
9		1050[2]			6
10	Glycogen	241			7
11	Phospholipid, %		5.72[3]		4
	Rabbit				
12	Water, %	78.0			8, 9
13		79.0(77.9-79.8)			10
14		80.0			11
15		78.0			12
16			77.1		13
17			77.9	78.0	14
18	Boron	3.94[4]			15
19	Bromine	0.065			16
20	Calcium	67.21			17
21	Chlorine	1365			12
22	Copper	2.23[4]			2
23	Iron	12.4			18
24	Magnesium	50.71			17
25	Manganese	0.028[6]			8
26		0.021			3
27	Nitrogen, total				10
28	Phosphorus, total	1055(774-1326)[7]			10
29	Potassium	676[1]	212(174-238)[8]		B, 17, C, 13
30	Sodium	491[1]	238[9]		17
31		122[5]			12
32	Zinc	1.06[6]			19
33		2.11[10]			20
34	Cholesterol, total, %		0.57(0.40-0.83)[11]		4
35			0.45(0.36-0.60)[12]		4
36	Creatine[13]	244	176	170	B, 21, C, D, 14
37		211	201(158-234)	195(160-228)	B, 22, C, D, 23
38		223(186-256)	150(112-225)[14]		B, 24, C, 25
39	Glycogen[15]	455(350-600)[2]	542		B, 10, C, 26
40		483(334-640)[2]			27
41		108[2]			28
42		380[2]			29
43		670[2]			30
44	Phospholipid, %		9.12[3]		4

/1/ mg/100 g dry weight /2/ Recalculated from g/100 ... mg/kg dry weight ... wet weight , ... lated from g , ... weight. /10/ ... 96.5(76-144) [... g wet weight. /15/ Right atrium· 512 [26] ... /15/ Right atrium·

Part III. RODENTS (Continued)

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Reference
	(A)	(B)	(C)	(D)	(E)
			Rat		
45	Water, %	77.4			31
46		76.6(76.0-77.2)			32
47		78.1			12
48		77.3			33
49		77.1[16]			34
50		76.9[16]			35
51		77.2			36
52		80.6			37
53		76.5			38
54		77.7			39
55	Bromine	0.295			16
56	Calcium	70[1]			40
57		8 1(2.7-19.7)			41
58		53 9(51.5-61.7)[1]			42
59	Chlorine	87.5[17]			12
60		96[5]			33
61		260[2]			43
62		111			44
63		83 7[5]			39
64	Copper	0.19[18]			37
65		2 8[1]			2
66	Iron	7.2(5.0-11 1)			45
67	Magnesium	100[1]			40
68		22.3(17.6-25 9)			41
69	Manganese	0 057[18]			38
70	Phosphorus, total	221[19]			34
71		222[19]			35
72		940[1]			40
73		113(87-134)			41
74		881(714-1118)[1]			42
75		255[5]			39
76		124			46
77	Potassium	318			31
78		329			12
79		314[20]			33
80		313[19]			34
81		332[19]			35
82		1700[1]			40
83	Sodium	86.7[5]			31
84		91.8[5]			33
85		90 1[19]			34
86		88.3			35
87		300[1]			40
88	Cholesterol, total, %		0.53(0.34-0 62)		4
89	Collagen	640[21]		2960[1]	B, 39, D, 47
90	Creatine	225			48
91		174(162-195)[14]			49
92		190			50
93		210(190-260)[2]			51
94		207			52
95		193(179-218)			53
96		188			54
97	Glycogen	542			55
98		341			56
99		266(190-380)			57
100		582(517-662)			58
101		478			59

/1/ mg/100 g dry weight /2/ Recalculated from g/100 g wet weight. /5/ Recalculated from mM/kg wet weight. /14/ Recalculated from mg/g wet weight. /16/ Recalculated from g/100 g dry weight to per cent of wet tissue. /17/ Recalculated from mEq/kg of tissue water. /18/ Recalculated from mg/kg dry weight. /19/ Recalculated from mM/100 g dry weight. /20/ Recalculated from mEq/kg dry weight. /21/ Recalculated from g/kg wet weight.

Part III: RODENTS (Concluded)

	Chemical	Total Heart	Ventricle		Reference
			Left	Right	
	(A)	(B)	(C)	(D)	(E)
	Rat (concluded)				
102	Glycogen (concluded)	498(391-635)			60
103		659			61
104		520[2]			62
105		451			63
106		442(240-680)			64
107	*Phospholipid, %*		7.95[3]		4

/2/ Recalculated from g/100 g wet weight. /3/ Recalculated.

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Part IV. ARTIODACTYLS AND PERISSODACTYLS

	Chemical	Total Heart	Ventricle		Reference
			Left	Right	
	(A)	(B)	(C)	(D)	(E)
			Cattle		
1	Water, %	77.4[1]	78.8		B,1;C,2
2		65.8			1
3	Bromine	0			3
4	Calcium		5.6	4.5	4
5			1.94[2]		2
6	Copper	1.56[3]			5
7		0.76[4,5]			6
8	Iron		6.8[2]		2
9	Magnesium[6]		27.2[2]	26.5[7]	C,2,D,7
10			16.1	16.1	4
11	Manganese	0.028			8
12	Phosphorus, total	211[4,8]	239	233	B,1;C,D,4
13		158[8]	214[2]		B,1,C,2
14	Potassium		288	266	4
15			253(247-259)[2]		2
16	Sodium		78.5	90	4
17			164(130-186)[2]		2
18	Tin	0.15[5]			9
19	Collagen		1930[9]	3760[9]	10
20	Creatine	215(207-220)	305	266	B,11,C,D,12
21	Fat	4390[8]			1
22		19.45[10]			1
			Horse		
23	Water, %	63.0			13
24	Copper	1.76[3]			5
25	Tin	0.24[5]			9
26	Zinc	1.58[5]			14
27		7.1			13
28	Glycogen	330[8]			15
			Pig		
29	Aluminum	0.55			
30	Copper	1.49[3]			16
31	Manganese	0.020			5
32	Collagen				8,17
			2180[9]	3380[9]	10
			Sheep		
33	Copper	1.79[3]			
34	Manganese	0 029			5
35	Tin	0.24			8
36	Creatine	283(208-339)			9
			342	267	B,18,C,D,12

/1/ Lean cattle /2/ Recalculated from g of the metallic oxides/100 g dry weight to mg of the element/100 g wet weight /3/ Recalculated from mg/kg dry weight to mg/100 g dry weight. /4/ Calf. /5/ Recalculated from mg/kg wet weight /6/ Right atrium, 19 [7]. /7/ Recalculated from mg/g wet weight. /8/ Recalculated from g/100 g wet weight /9/ mg/100 g dry weight. /10/ g/100 g wet weight.

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Part III: RODENTS (Concluded)

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Reference
	(A)	(B)	(C)	(D)	(E)
	Rat (concluded)				
102	Glycogen (concluded)	498(391-635)			60
103		659			61
104		520[2]			62
105		451			63
106		442(240-680)			64
107	Phospholipid, %		7.95[3]		4

/2/ Recalculated from g/100 g wet weight. /3/ Recalculated.

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24. FRACTIONAL EXTRACTION OF DIFFUSIBLE SUBSTANCES FROM CAPILLARIES. MAN, DOG

L_c is the fraction of arterial concentration lost in a *single* circulation through the capillary bed. Diffusion through *capillary* walls is affected by blood flow per amount of tissue, as well as by certain physical attributes of the diffusing molecules. [illegible] equilibrium across the *capillary* wall is complete, or nearly complete, within a single circulation for t[illegible] $Kr^{79,81}$ [10,11], N_2, *He*, Xe^{127} [11], and antipyrine [8]. [illegible]s otherwise indicated (cf. Introduction).

	Tissue	Substance	Weight	mg	Blood Flow ml/min/100 g tissue	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Man					
1	Forearm	H^2OH	19	0 94(0.91-0 97)		1
2		SCN^-	78	0.48(0.38-0.56)		
3	Lung	H^2OH	19	0.43(0.36-0.54)[c]	4800-10,800[1]	2
4		SCN^-	78	0.07(0.03-0.09)[c]		
	Dog					
5	Gracilis muscle	K^{42}	42	0.78[2]	1.9	3
6		K^{42}	42	0.67[2]	4 0	
7		K^{42}	42	0.50[2]	8 6	
8		K^{42}	42	0 43[2]	12.9	
9	Head, intact	H^3OH	20	0 89[2]		4
10		Na^{22}	22	0 43[2]		
11		SCN^-	78	0 44[2]		
12		Creatinine	113	0.44[2]		
13		Inulin	5100	0.16(0.14-0.17)		
14	Heart, intact	K^{42}	42	0.67(0.56-0.77)	88(75-100)	5
15	Hind leg, intact	H^2OH	19	0.70(0.62-0.77)[3]		4
16		H^3OH	20	0 65[2,3]		
17		Na^{22}	22	0.36[2]		
18		Cl^{36}	36	0 49(0 39-0 59)		
19		Urea	60	0.60(0.54-0.69)		
20		SCN^-	78	0.54(0.32-0.77)		
21		Xylose	150	0.28(0.25-0.31)		
22		Antipyrine	188	0.62(0 59-0 65)		
23		$Fe(CN)_6$	212	0.13(0.11-0.14)		
24		Inulin	5100	0 24(0 08-0.40)		
25	Kidney	H^2OH	19	0.93(0 91-0 96)[c]		6
26		SCN^-	78	0 77(0.64-0.85)[c]		
27		PAH[4]	194	0.95(0.69-0.98)[c]		
28		Inulin	5100	0.79(0 49-0.94)[c]		
29	Liver, intact	H^2OH	19	0.97		4
30		Urea	60	0.90(0.88-0.91)		
31		SCN^-	78	0.22[2]		
32		Inulin	5100	0.15[2]		
33	Lung	H^2OH, H^3OH	19, 20	0.56(0.38-0 68)	1500-2400[1]	7

/1/ Total blood flow in lungs /2/ From single determinations. /3/ Deviations from complete equilibration (L_c = 1 00) may be due to a small amount of arterio-venous shunting [1,8] /4/ p-aminohippurate.

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Part V: BIRDS

	Chemical	Total Heart	Ventricle Left	Ventricle Right	Reference
	(A)	(B)	(C)	(D)	(E)
	Duck[1]				
1	Cholesterol, total, %		0.52		1
2	Phospholipid, %		7.80[2]		1
	Hen				
3	Cholesterol, total, %		0.54(0.41-0.70)		1
4	Phospholipid, %		7.56[2]		1
	Owl				
5	Cholesterol, total, %		0.56(0.52-0.64)		1
6	Phospholipid, %		6.16[2]		1
	Pigeon				
7	Magnesium		56(35-96)[3]		2
8	Cholesterol, total, %		0.52(0.29-0.59)		1
9	Creatine		235[3]		2
10	Glycogen	155			3
11	Phospholipid, %		7.28[2]		1
	Sparrow				
12	Cholesterol, total, %		0.57		1
13	Phospholipid, %		8.55[2]		1

/1/ Wild. /2/ Recalculated. /3/ Recalculated from mg/g wet weight.

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23. CAPILLARY FILTRATION COEFFICIENTS: VERTEBRATES

Kp is the proportionality constant relating the rate of net fluid transport by filtration (+F), or reabsorption (-F), to effective filtration pressure. $F = Kp[(pC-pT)-(\pi p-\pi t)]$, where pC is the mean capillary hydrostatic pressure, pT the interstitial fluid pressure, and πp and πt the colloid osmotic pressures of plasma and interstitial fluid, respectively. Values in parentheses are ranges, estimate "b" (cf. Introduction).

	Animal	Tissue	Temp °C			
	(A)	(B)	(C)			
1	Man	Forearm, intact	37	0.004[illegible]		1,2
2	Cat	Brain	37	0 045	0.0014	3
3		Hind leg, isolated	36(34-38)	0 011(0.005-0.017)	0.00034	4,5
4			10(8-12)	0 006(0.004-0.008)		6
5	Dog	Hind leg, isolated	37	0.014(0.010-0.018)		4
6	Rat	Hindquarters, isolated	37	0.033(0 025-0.041)		7
7	Frog	Mesenteric capillaries	24(22-26)		0 0076	8
8			0(-2 to +2)		0 0026	9

Contributor. Renkin, Eugene M.

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27. PERMEABILITY OF CELL SURFACES: ANIMALS, PLANTS

Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I. TO WATER

Values are expressed in the number of cubic micra of water that pass through 1 square micron of cell surface, per minute, per atmosphere of difference in osmotic pressure. *Unless otherwise indicated, experimental temperatures are 18-22°C.*

	Species (A)	Cell (B)	Permeability (C)	Reference (D)
	Vertebrates			
1	Man	Erythrocyte	3.6	1
2		Leukocyte	1.35	2
3	Cattle (Bos taurus)	Erythrocyte	2.5	3
4	Chick, mouse, rat	Fibroblasts from tissue culture of mouse and rat tumors, and of chick and rat embryos	(0.4-1.0)[1]	4
5	Fish, zebra (Danio rerio)	Ovarian egg	1.3	5
6		Shed egg	0.02	5
7	Frog (Rana temporaria)	Ovarian egg	4	5
8		Body cavity egg	0.06	5
9	Rabbit (Oryctolagus cuniculus)	Erythrocyte	(1.4-4.8)	6
10		Leukocyte	0.29[2]	2
11	Toad (Xenopus laevis)	Body cavity egg	0.07	5
	Invertebrates			
12	Ameba (Amoeba chaos chaos)		0.01	5
13	(A. proteus)		0.01	7
14	Clam (Cumingia tellenoides)	Unfertilized egg	0.49	3
15	Gregarina sp		(0.20-0.25)	8
16	Oyster (Ostrea virginica)	Unfertilized egg	(0.6-0.7)	9
17	Polymyxa sp		0.01	10
18	Sand dollar (Dendraster sp)	Unfertilized egg	(0.1-0.4)	3
19	Sea urchin (Arbacia punctulata)	Fertilized egg	(0.2-0.3)	11-13
20		Unfertilized egg	0.09[3]	3,14
21	(Anthocidaris crassispinia)	Unfertilized egg	0.28(0.27-0.30)	15
22	(Paracentrotus lividus)	Fertilized egg	0.2[4]	16
23		Unfertilized egg	0.1[4]	3
24	(Pseudocentrotus depressus)	Unfertilized egg	0.21(0.18-0.24)	15
25	(Strongylocentrotus franciscanus)	Unfertilized egg	(0.1-0.4)	3
26	Starfish (Patiria miniata)	Unfertilized egg	(0.1-0.4)	3
27	(Pisaster ochraceus)	Unfertilized egg	(0.1-0.4)	3
28	Water flea (Daphnia longispinia)	Ovarian egg	0.04(0.03-0.07)	17
29	Worm (Chaetopterus	Fertilized egg	0.61(0.33-1.20)	18
30	pergamentoceus)	Unfertilized egg	0.49(0.23-1.09)	18
31	(Urechis caupo)	Unfertilized egg	0.27	19
32	Zoothamnium sp		(0.12-0.25)	3,9
	Plants			
33	Algae (Fucus vesiculosus)		0.16	3,20
34	(Halicystis osterhoutii)		2.3	21
35	(Nitella flexilis)		460	22
36	(Spirogyra sp)		16	6
37	Fern (Salvinia auriculata)	Leaf	0.55	3,23
38	Onion (Allium sp)	Pulp	0.30	3,24

/1/ 24-28°C. /2/ Outward flow = 1.16. /3/ Outward flow = 0.14. /4/ 13-15°C.

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25. TRANSCAPILLARY EXCHANGE OF LARGE MOLECULES: MAN, DOG, GUINEA PIG

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal[1]	Substance	Molecular Weight	Transcapillary Exchange Rate fraction in plasma/min	Reference
	(A)	(B)	(C)	(D)	(E)
1	Man	Serum albumin[2]	69,000	0.00096	1
2				1/3 at 0.0038 2/3 at 0.00048	2
3		Serum γ-globulin[2]	156,000	0.0022(0.0012-0.0031)	3
4	Dog	Dextran	5,200[3]	0.033(0.029-0.037)	4
5			20,000[3]	0.0113(0.0097-0.0126)	
6			60,000[3]	0.0016(0.0013-0.0019)	
7			80,000[3]	0.0004(0.0003-0.0006)	
8		Serum albumin[2]	69,000	0.00092(0.00035-0.00158)	5
9		Serum γ-globulin[2]	156,000	0.00077	6
10	Guinea pig	Ferric β_1-globulin	90,000	0.0059(0.0025-0.0110)	7

/1/ Intact. /2/ Measured by use of I^{131}-labelled protein. /3/ Average molecular weight of fractions, separated by alcohol precipitation.

Contributor: Renkin, Eugene M.

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26. CAPILLARY PERMEABILITY COEFFICIENTS OF VARIOUS SUBSTANCES IN TISSUE: CAT

Capillary endothelium is more highly permeable to lipid-soluble substances such as antipyrine than to lipid-insoluble substances. Presumably such substances penetrate endothelial cells as well as capillary pores. The oil:water partition coefficient of antipyrine is about 0.05, while that of the other substances listed in this table is less than 0.0002. Permeability to lipid-insoluble molecules is determined principally by molecular size. Data are means of results obtained by perfusing the substances dissolved in blood through muscle tissue in isolated hindlimbs of cat. Capillary surface area per gram of skeletal muscle is estimated to be 70 sq cm.

	Substance	Molecular Weight	Capillary Permeability[1] per g of tissue x (10^{-6})	Apparent Diffusion Area[2] cm/g of tissue x (10^3)
	(A)	(B)	(C)	(D)
1	Water	18	36[3]	1.1[3]
2	NaCl	58.4	23	1.0
3	Urea	60.1	18	0.94
4	Glucose	180	6.4	0.70
5	Sucrose	342	3.6	0.48
6	Raffinose	594	2.7	0.42
7	Inulin	5100	0.42	0.19
8	Myoglobin	16,800	0.05	0.03
9	Hemoglobin	67,800	0.00	0.00
10	Antipyrine	188	>550	

/1/ Coefficient of permeability (P) as moles diffusing per second for each mole of concentration difference per liter across membrane. /2/ Apparent diffusion area per path length, $A/\Delta x = P/D$, where D = free diffusion coefficient of solute in aqueous solution. Diminution of this quantity $(A/\Delta x)$ with increasing molecular weight is attributable to restriction of passage to larger molecules through capillary pores. Estimated mean pore radius in capillaries of hindleg of cat is 30-45 Å. /3/ Obtained by extrapolating from other data to molecular weight of water.

Contributor: Renkin, Eugene M.

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27. PERMEABILITY OF CELL SURFACES. ANIMALS, PLANTS (Continued)

Part II: *TO INORGANIC IONS* (Concluded)

	Ion	Species	Cell	Permeability			Reference
				Flow	Rate	Unit of Measurement	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Invertebrates (concluded)						
56	Bromide	Squid (Loligo pealei)	Nerve	I	4.3	cm/hr x 10^{-6}	13
57	Chloride	Cuttlefish (Sepia officinalis)	Nerve	I	0.6	M/sq cm/impulse x 10^{-12}	18
	Plants						
58	Sodium	Algae (Nitella coronata)		I	28.8	M/sq cm/min x 10^{-8}	21
59		(Valonia macrophysa)		I	0.09		
60		(V. ventricosa)		I	0.01		22
61		Waterplant (Elodea sp)		I	28.8	M/sq cm/min x 10^{-8}	21
62	Potassium	Algae (Nitella clavata)		I	0.01	M/sq cm/min x 10^{-8}	21
63		(N. coronata)		I	157		
64		(N. flexilis)		I	0.01		
65		(Valonia macrophysa)		I	0.44		
66		(V. ventricosa)		I	0.05		22
67		Waterplant (Elodea sp)		I	157	M/sq cm/min x 10^{-8}	21
68	Rubidium	Algae (Nitella coronata)		I	510	M/sq cm/min x 10^{-8}	21
69		(Valonia ventricosa)		I	1.1		23
70		Waterplant (Elodea sp)		I	51	cm/hr x 10^{-6}	21
71	Bromide	Algae (Nitella coronata)		I	0.0002	M/sq cm/min x 10^{-8}	21
72		Waterplant (Elodea sp)		I	4.3	cm/hr x 10^{-6}	21
73	Chloride	Algae (Nitella coronata)		I	0.0072	M/sq cm/min x 10^{-8}	21
74		(Valonia ventricosa)		I	0.06		22
75	Phosphate	Algae (Nitella coronata)		I	25	M/sq cm/min x 10^{-8}	21
76		(N. flexilis)		I	(1-6)	M/sq cm/sec x 10^{-12}	8
77	Iodide	Algae (Valonia macrophysa)		I	0.0018	M/sq cm/min x 10^{-8}	21

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…RMEABILITY OF CELL SURFACES: ANIMALS, PLANTS (Continued)

Part II: TO INORGANIC IONS

Experimental temperatures range from 36-38°C for mammalian cells, and from 15-25°C for all other
Flow: I = inward, O = outward.

	Ion (A)	Species (B)	Cell (C)	Flow (D)	Rate (E)	Unit of Measurement (F)	
			Vertebrates				
1	Sodium	Man	Erythrocyte	I	(0.6-1.6)	cm/hr x 10^{-6}	
2				O	(6-16)		
3		Cat (Felis catus)	Erythrocyte	I	5	cm/hr x 10^{-6}	
4			Nerve, desheathed popliteal	O	3.9	M/sq cm/sec x 10^{-12}	
5		Chicken (Gallus domesticus)	Erythrocyte	I	2	cm/hr x 10^{-6}	
6				O	49		
7		Dog (Canis familiaris)	Erythrocyte	I	14	cm/hr x 10^{-6}	
8		Frog (Rana esculenta)	Musculus extensor longus digitorum IV	I	10.2	M/sq cm/sec x 10^{-12}	6
9				O	10.9		
10		(R. temporaria)	Erythrocyte	I	2	cm/hr x 10^{-6}	2
11			Sartorius muscle	I	13	M/sq cm/sec x 10^{-12}	7
12				O	16		
13		Rabbit (Oryctolagus sp)	Erythrocyte	I	100 (in vivo)	cm/hr x 10^{-6}	5
14		Rat (Rattus rattus)	Diaphragm	O	26	M/sq cm/sec x 10^{-12}	8
15	Potassium	Man	Erythrocyte	I	1.7	mM/sq cm/hr x 10^{-7}	9
16				O	1.6		
17		Cat (Felis catus)	Erythrocyte	I	1.5	mM/sq cm/hr x 10^{-7}	10
18		Dog (Canis familiaris)	Erythrocyte	I	0.08	mM/sq cm/hr x 10^{-7}	11
19		Frog (Rana esculenta)	Musculus adductor longus digitorum IV	I	6	M/sq cm/sec x 10^{-12}	7
20				O	8		
21			Musculus extensor longus digitorum IV	I	4(3-5)		6
22				O	4.9(4-6)		
23		(R. pipiens)	Erythrocyte	I	5.3	mM/sq cm/hr x 10^{-7}	10
24		(R. temporaria)	Sartorius muscle	I	5	M/sq cm/sec x 10^{-12}	7
25				O	7		
26		Guinea pig (Cavia porcellus)	Erythrocyte	I	3.2	mM/sq cm/hr x 10^{-7}	10
27		Rabbit (Oryctolagus sp)	Erythrocyte	I	2.1	mM/sq cm/hr x 10^{-7}	10
28		Rat (Rattus rattus)	Gastrocnemius muscle	I	130	cm/hr x 10^{-6}	5
29			Erythrocyte	I	5.4	mM/sq cm/hr x 10^{-7}	10
30			Diaphragm	I	38.5	M/sq cm/sec x 10^{-12}	8
31			Gastrocnemius muscle	I	700	cm/hr x 10^{-6}	5
32	Chloride	Frog (Rana esculenta)	Sartorius muscle	I	11	M/sq cm/sec x 10^{-12}	6
33	Phosphate	Frog (R. temporaria)	Gastrocnemius muscle	I	(15-21)	cm/hr x 10^{-6}	5
			Invertebrates				
34	Sodium	Cuttlefish (Sepia officinalis)	Nerve	I	35	M/sq cm/sec x 10^{-12}	12
35				O	40		
36				I	10	M/sq cm/impulse x 10^{-12}	8
37				O	6		
38		Squid (Loligo pealei)	Nerve	I	4.5	M/sq cm/impulse x 10^{-12}	13
39		(L. forbesi)	Nerve	I	61(16-153)	M/sq cm/sec x 10^{-12}	14
40				I	10(5-15)	M/sq cm/impulse x 10^{-12}	
41				O	6.6(4.5-9 6)		
42		Worm (Urechis caupo)	Egg	I	600	M/sq cm/min x 10^{-8}	15
43	Potassium	Crab (Carcinus maenas)	Nerve	I	19	M/sq cm/sec x 10^{-12}	16
44				O	22(16-33)		
45				I	0.5	M/sq cm/impulse x 10^{-12}	17
46				O	2.9(2.7-3.6)		
47		Cuttlefish (Sepia officinalis)	Nerve	I	21	M/sq cm/seq x 10^{-12}	8
48				O	28		
49				I	0.39	M/sq cm/impulse x 10^{-12}	
50				O	4.7		
51		Squid (Loligo pealei)	Nerve	I	1250	cm/hr x 10^{-6}	13
52		(L. forbesi)	Nerve	O	3.0(2.6-3.4)	M/sq cm/impulse x 10^{-12}	18
53		Starfish (Pisaster ochraceus)	Egg	I	600	M/sq cm/min x 10^{-8}	19
54	Rubidium	Squid (Loligo pealei)	Nerve	I	51	cm/hr x 10^{-6}	13
55		Starfish (Patiria miniata)	Egg	I	600	M/sq cm/min x 10^{-8}	20

27. PERMEABILITY OF CELL SURFACES: ANIMALS, PLANTS (Continued)

Part III. TO ORGANIC SUBSTANCES (Continued)

	Substance (A)	Species (B)	Permeability (C)	Reference (D)
		Plants		
61	Ethylene glycol	Algae (Ceramium diaphanum)	49.8	3
62		Algae (Chara ceratophylla)	71.6	9
63		Algae (Melosira sp)	22.5	3
64		Algae (Pylaiella litoralis)	5.8	3
65		Algae (Spirogyra sp)	6.6	3
66		Bacteria (Beggiatoa mirabilis)	83.4	3
67		Moss (Plagiothecium denticulatum)	2	3
68		Oyster plant (Rhoeo discolor)	10.4	3
69		Turmeric (Curcuma rubricaulis)	6.6	3
70	Propylene glycol	Algae (Chara ceratophylla)	145	9
71	Glycerol	Algae (Ceramium diaphanum)	1.3	3
72		Algae (Chara ceratophylla)	1.2	9
73		Algae (Melosira sp)	2	3
74		Algae (Pylaiella litoralis)	0.1	3
75		Algae (Spirogyra sp)	0.2	3
76		Bacteria (Bacterium paracoli)	3.3	3
77		Bacteria (Beggiatoa mirabilis)	63.6	3
78		Maianthemum (Maianthemum sp)	9.8[3]	10
79		Moss (Plagiothecium denticulatum)	0.02	3
80		Oyster plant (Rhoeo discolor)	0.7	3
81		Turmeric (Curcuma rubricaulis)	0.1	3
82	Erythritol	Algae (Ceramium diaphanum)	0.1	3
83		Algae (Chara ceratophylla)	0.08	9
84		Algae (Melosira sp)	0.8	3
85		Algae (Pylaiella litoralis)	0.007	3
86		Algae (Spirogyra sp)	0.02	3
87		Bacteria (Bacterium paracoli)	0.3	3
88		Bacteria (Beggiatoa mirabilis)	50.3	3
89		Moss (Plagiothecium denticulatum)	0.004	3
90		Oyster plant (Rhoeo discolor)	0.03	3
91		Turmeric (Curcuma rubricaulis)	0.02	3
92	Mannitol	Algae (Chara ceratophylla)	<0.05	9
93	Monoacetin	Algae (C. ceratophylla)	26.6	9
94	Diacetin	Algae (C. ceratophylla)	133	9
95	Acetamide	Algae (C. ceratophylla)	90	3
96		Algae (Melosira sp)	28.2	3
97		Algae (Pylaiella litoralis)	16.8	3
98		Moss (Plagiothecium denticulatum)	4	3
99		Turmeric (Curcuma rubricaulis)	4.8	3
100	Malonamide	Algae (Ceramium diaphanum)	1.5	3
101		Algae (Chara ceratophylla)	0.2	3
102		Algae (Melosira sp)	1.1	3
103		Algae (Pylaiella litoralis)	0.1	3
104		Algae (Spirogyra sp)	0.1	3
105		Bacteria (Bacterium paracoli)	1.7	3
106		Bacteria (Beggiatoa mirabilis)	94.8	3
107		Maianthemum (Maianthemum sp)	5.5[3]	10
108		Moss (Plagiothecium denticulatum)	0.05	3
109		Oyster plant (Rhoeo discolor)	0.01	3
110		Turmeric (Curcuma rubricaulis)	0.02	3
111	Propionamide	Algae (Ceramium diaphanum)	168	3
112		Algae (Chara ceratophylla)	216	3
113		Algae (Melosira sp)	180	3
114		Algae (Pylaiella litoralis)	84	3
115		Algae (Spirogyra sp)	27	3
116		Moss (Plagiothecium denticulatum)	12	3
117		Oyster plant (Rhoeo discolor)	9.6	3
118		Turmeric (Curcuma rubricaulis)	13.2	3
119	Saccharose	Algae (Chara ceratophylla)	0.05	3
120		Algae (Melosira sp)	0.4	3
121		Algae (Pylaiella litoralis)	0.0004	3
122		Bacteria (Beggiatoa mirabilis)	8.1	3
123		Moss (Plagiothecium denticulatum)	0.0005	3
124		Turmeric (Curcuma rubricaulis)	0.0005	3

/3/ Value given in moles per minute x 10^{-4}.

Part III: TO ORGANIC SUBSTANCES

Values are expressed in moles per square centimeter of surface area per minute per gram mole difference in concentration x 10^{-8}, unless otherwise indicated. Temperatures range from 20-25°C.

	Substance (A)	Species (B)	Permeability (C)	Reference (D)
	Vertebrates[1]			
1	Ethylene glycol	Ground hog	246	1
2		Ox	9.6	2
3	Diethylene glycol	Ox	4.5	1
4	Triethylene glycol	Ox	2	1
5	Trimethylene glycol	Ox	6	1
6	Propylene glycol	Ox	19.8	1
7	Glycerol	Man	9	1
8		Ground hog	163	1
9		Ox	0.11	2
10	Erythritol	Ground hog	31.7	1
11		Ox	<0.003	1
12	Mannitol	Man	<0.33	1
13		Ground hog	2	1
14		Ox	<0.003	1
15	Propyl alcohol	Ox	636	3
16	Monoacetin	Ox	6.8	1
17	Diacetin	Ox	62.5	1
18	Acetamide	Ox	283	4
19	Butyramide	Ox	163	4
20	Formamide	Ox	293	4
21	Propionamide	Ox	114	4
22	Sucrose	Man	0	1
23	Xylose	Ground hog	0.66	1
24		Ox	<0.003	1
25	Urea	Man	1166	1
26		Ground hog	1666	1
27		Ox	1080	2
28	Thiourea	Ground hog	138	1
29		Ox	1.2	1
	Invertebrates[2]			
30	Ethylene glycol	Clam (Cumingia tellenoides)	156(151-163)	5
31		Marine worm (Chaetopterus pergamentaceus)	143(140-153)	5
32		Sea urchin (Arbacia punctulata)	36(29-56)	5-7
33		Starfish (Asterias sp)	102(50-182)	7
34		Worm (Phascolosoma gouldi)	7.3	4
35		Protozoa (Gregarina sp)	40.2	3
36	Diethylene glycol	Sea urchin (Arbacia punctulata)	26	8
37		Worm (Phascolosoma gouldi)	3.7	4
38	Triethylene glycol	Worm (P. gouldi)	1.2	4
39	Trimethylene glycol	Sea urchin (Arbacia punctulata)	43	1
40		Worm (Phascolosoma gouldi)	7.3	4
41	Tetraethylene glycol	Worm (P. gouldi)	0.4	4
42	Propylene glycol	Sea urchin (Arbacia punctulata)	77	8
43		Worm (Phascolosoma gouldi)	11.7	4
44		Protozoa (Gregarina sp)	79.2	3
45	Glycerol	Marine worm (Chaetopterus pergamentaceus)	62(58-69)	5
46		Sea urchin (Arbacia punctulata)	5	1
47		Worm (Phascolosoma gouldi)	<0.004	4
48		Protozoa (Gregarina sp)	1.1	3
49	Monoacetin	Worm (Phascolosoma gouldi)	0.6	4
50	Diacetin	Worm (P. gouldi)	4.5	4
51	Acetamide	Sea urchin (Arbacia punctulata)	(55-60)	6
52		Worm (Phascolosoma gouldi)	15.8	4
53	Butyramide	Sea urchin (Arbacia punctulata)	(338-394)	6
54		Worm (Phascolosoma gouldi)	410	4
55	Formamide	Worm (P. gouldi)	9.8	4
56	Malonamide	Protozoa (Gregarina sp)	15	3
57	Propionamide	Sea urchin (Arbacia punctulata)	(134-150)	6
58		Worm (Phascolosoma gouldi)	62.3	4
59	Urea	Worm (P. gouldi)	1.6	4
60	Thiourea	Worm (P. gouldi)	2	4

/1/ Erythrocytes. /2/ Unfertilized eggs, except values for worm (Phascolosoma gouldi) which are for permeability of erythrocyte surface.

Part III: TO ORGANIC SUBSTANCES (Continued)

	Substance (A)	Species (B)	Permeability (C)	Reference (D)
		Plants		
61	Ethylene glycol	Algae (Ceramium diaphanum)	49.8	3
62		Algae (Chara ceratophylla)	71.6	9
63		Algae (Melosira sp)	22.5	3
64		Algae (Pylaiella litoralis)	5.8	3
65		Algae (Spirogyra sp)	6.6	3
66		Bacteria (Beggiatoa mirabilis)	83.4	3
67		Moss (Plagiothecium denticulatum)	2	3
68		Oyster plant (Rhoeo discolor)	10.4	3
69		Turmeric (Curcuma rubricaulis)	6.6	3
70	Propylene glycol	Algae (Chara ceratophylla)	145	9
71	Glycerol	Algae (Ceramium diaphanum)	1.3	3
72		Algae (Chara ceratophylla)	1.2	9
73		Algae (Melosira sp)	2	3
74		Algae (Pylaiella litoralis)	0.1	3
75		Algae (Spirogyra sp)	0.2	3
76		Bacteria (Bacterium paracoli)	3.3	3
77		Bacteria (Beggiatoa mirabilis)	63.6	3
78		Maianthemum (Maianthemum sp)	9.8[3]	10
79		Moss (Plagiothecium denticulatum)	0.02	3
80		Oyster plant (Rhoeo discolor)	0.7	3
81		Turmeric (Curcuma rubricaulis)	0.1	3
82	Erythritol	Algae (Ceramium diaphanum)	0.1	3
83		Algae (Chara ceratophylla)	0.08	9
84		Algae (Melosira sp)	0.8	3
85		Algae (Pylaiella litoralis)	0.007	3
86		Algae (Spirogyra sp)	0.02	3
87		Bacteria (Bacterium paracoli)	0.3	3
88		Bacteria (Beggiatoa mirabilis)	50.3	3
89		Moss (Plagiothecium denticulatum)	0.004	3
90		Oyster plant (Rhoeo discolor)	0.03	3
91		Turmeric (Curcuma rubricaulis)	0.02	3
92	Mannitol	Algae (Chara ceratophylla)	<0.05	9
93	Monoacetin	Algae (C. ceratophylla)	26.6	9
94	Diacetin	Algae (C. ceratophylla)	133	9
95	Acetamide	Algae (C. ceratophylla)	90	3
96		Algae (Melosira sp)	28.2	3
97		Algae (Pylaiella litoralis)	16.8	3
98		Moss (Plagiothecium denticulatum)	4	3
99		Turmeric (Curcuma rubricaulis)	4.8	3
100	Malonamide	Algae (Ceramium diaphanum)	1.5	3
101		Algae (Chara ceratophylla)	0.2	3
102		Algae (Melosira sp)	1.1	3
103		Algae (Pylaiella litoralis)	0.1	3
104		Algae (Spirogyra sp)	0.1	3
105		Bacteria (Bacterium paracoli)	1.7	3
106		Bacteria (Beggiatoa mirabilis)	94.8	3
107		Maianthemum (Maianthemum sp)	5.5[3]	10
108		Moss (Plagiothecium denticulatum)	0.05	3
109		Oyster plant (Rhoeo discolor)	0.01	3
110		Turmeric (Curcuma rubricaulis)	0.02	3
111	Propionamide	Algae (Ceramium diaphanum)	168	3
112		Algae (Chara ceratophylla)	216	3
113		Algae (Melosira sp)	180	3
114		Algae (Pylaiella litoralis)	84	3
115		Algae (Spirogyra sp)	27	3
116		Moss (Plagiothecium denticulatum)	12	3
117		Oyster plant (Rhoeo discolor)	9.6	3
118		Turmeric (Curcuma rubricaulis)	13.2	3
119	Saccharose	Algae (Chara ceratophylla)	0.05	3
120		Algae (Melosira sp)	0.4	3
121		Algae (Pylaiella litoralis)	0.0004	3
122		Bacteria (Beggiatoa mirabilis)	8.1	3
123		Moss (Plagiothecium denticulatum)	0.0005	3
124		Turmeric (Curcuma rubricaulis)	0.0005	3

/3/ Value given in moles per minute $\times 10^{-4}$.

Part III: TO ORGANIC SUBSTANCES (Concluded)

	Substance (A)	Species (B)	Permeability (C)	Reference (D)
		Plants (concluded)		
125	Urea	Algae (Ceramium diaphanum)	5	3
126		Algae (Chara ceratophylla)	6.7	9
127		Algae (Melosira sp)	2.5	3
128		Algae (Pylaiella litoralis)	0.5	3
129		Algae (Spirogyra sp)	1.1	3
130		Bacteria (Bacterium paracoli)	5	3
131		Bacteria (Beggiatoa mirabilis)	70.2	3
132		Maianthemum (Maianthemum sp)	(23.4-33.3)[3]	10
133		Moss (Plagiothecium denticulatum)	0.2	3
134		Oyster plant (Rhoeo discolor)	0.2	3
135		Turmeric (Curcuma rubricaulis)	0.09	3
136	Methyl urea	Algae (Ceramium diaphanum)	5.8	3
137		Algae (Chara ceratophylla)	11.4	3
138		Algae (Melosira sp)	7.2	3
139		Algae (Pylaiella litoralis)	1.9	3
140		Algae (Spirogyra sp)	1.7	3
141		Maianthemum (Maianthemum sp)	75[3]	10
142		Moss (Plagiothecium denticulatum)	0.7	3
143		Oyster plant (Rhoeo discolor)	0.5	3
144		Turmeric (Curcuma rubricaulis)	0.5	3
145	Thiourea	Algae (Chara ceratophylla)	12.8	9
146		Maianthemum (Maianthemum sp)	90[3]	10
147		Oyster plant (Rhoeo discolor)	21[3]	10

/3/ Value given in moles per minute x 10^{-4}.

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28. CARDIOVASCULAR AND PULMONARY REFLEXES. MAMMALS

	Receptors		Afferent Nerves	Effective Stimulus	Response	
	Type	Location			Cardiovascular	Pulmonary
	(A)	(B)	(C)	(D)	(E)	(F)
			Blood Vessel and Heart Reflexes			
1	Systemic arterial pressure receptors	Carotid sinus	Branch of glossopharyngeal	Increase of transmural pressure.	Fall in blood pressure; decrease in heart rate and cardiac output, peripheral vasodilatation due to decrease in vasoconstrictor tone.	Slowing or arrest of breathing; bronchoconstriction.
2		Common carotid	Branches of vagi and aortic nerves	Increase of transmural pressure.		
3		Aortic arch	Aortic depressor	Increase of transmural pressure.		
4		Mesenteric arteries (Pacinian corpuscles)	Splanchnic	Increase of transmural pressure.	Uncertain.	
5		Thoracic aorta	Dorsal roots of thoracic nerves 1-12	Increase of transmural pressure.	Peripheral vasodilatation.	
6	Systemic arterial chemoreceptors	Carotid bodies	Branch of glossopharyngeal	Asphyxia, anoxia, or hypercapnia.	Peripheral vasoconstriction; primary bradycardia, secondary reflex increase in heart rate due to hyperpnea.	Hyperpnea.
7		Aortic bodies (4 main groups)	Aortic nerves and/or vagi	Asphyxia, anoxia, or hypercapnia.		
8	Venous pressure receptors	Right and left atria	Vagi	Increase of transmural pressure or volume.	Fall in blood pressure and decrease in heart rate; change in blood volume (?).	
9	Pulmonary arterial pressure receptors	Pulmonary conus	Vagi	Increase of transmural pressure.	Fall in blood pressure and decrease in heart rate.	
10	Ventricular receptors	Wall of left ventricle	Vagi	Increase of transmural pressure.	Fall in blood pressure and decrease in heart rate.	
			Lung Reflexes			
11	Pulmonary deflation receptors	Small pulmonary vessels (?)	Vagi	Strong deflation; multiple minute embolism, or pulmonary congestion.	Fall in blood pressure and decrease in heart rate.	Rapid, shallow breathing.
12	Pulmonary stretch receptors	Smaller air passages	Vagi	Inflation of lungs.		Inhibition of breathing.
13	Slowly adapting bronchial receptors	Trachea and bronchi	Vagi	Inflation or deflation of lungs.		Inhibition of breathing; bronchoconstriction.
14	Rapidly adapting tracheal and bronchial receptors	Trachea and bronchi	Vagi	Mechanical or chemical.		Cough; bronchoconstriction.
15	Cough receptors	Bronchial tree	Sympathetic	Inhalation of irritant vapors.		Cough.
16	Deflation receptors	Muscles of chest wall (?)	Dorsal roots of thoracic nerves 1-4	Suction to trachea.		Inspiratory effort.

Contributor: Dawes, Geoffrey S.

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Part I: RESTING AND ACTION POTENTIALS OF SINGLE FIBERS

Magnitude, in millivolts (mv), determined by direct measurement with an intracellular microelectrode filled with 3M KCl. Technique: ISu = in situ, IVt = in vitro. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Animal	Tissue	Fiber Diameter[1] µ	No. of Observations	Technique	Membrane Potential[2] Resting mv	Action mv	Overshoot mv	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Man	Ventricle	16	5	ISu	65	95	30	1, 2
2	Cat	Ventricle	16 (10)		ISu	80(65-95)	100(80-120)	16(4-28)b	3
3		Atrium	10 (10)	625	IVt	60(36-91)	65(30-95)	4.7	4
4		Papillary muscle	16 (10)	160	IVt	88(86.8-89.2)b	116(115-117)b	28	5
5		Purkinje fiber	(13)		IVt	96	121	25	6
6	Dog	Ventricle	16 (11)	200	ISu	80(65-95)	100(80-120)	16(4-28)b	3
7		Ventricle	16 (11)	33	ISu	82(76-96)	102(96-114)		6
8		Atrium	10 (10)	100	ISu	85(68-94)	100(82-118)	15(1-29)b	3
9		Atrium	10 (10)	100	IVt	85(68-95)	105(82-120)	20	7
10		Atrium	10 (10)	50	IVt	83(70-94)	100(86-119)	17	8
11		Papillary muscle	16 (11)	100	IVt	85(70-95)	105(82-125)	20	7
12		Purkinje fiber	30 (22)	400	IVt	89(86-92)b	121(117-125)b	32	9
13		Purkinje fiber	30 (22)	312	IVt	90(78-102)b	121	31(21-41)b	10
14		Sinus			IVt	75(65-80)	84(70-98)	11	8
15	Goat	Purkinje fiber	75 (40)	57	IVt	94(78-110)b	135(123-147)b	41	10
16	Guinea pig	Ventricle	(13)	241	IVt	52.8	67.2	14.4	11
17		Atrium			ISu	57	68	11	12, 13
18	Mouse	Atrium	(8)	64	IVt	86(73-99)b	98(86-110)b	12	14
19	Rabbit	Ventricle	(11)	50	IVt	80	108	28	15
20		Atrium	(11)	30	IVt	78	97	19	16
21		Atrium	(11)	27	IVt	73	98	25	17
22		Atrium	(11)	35	IVt	73	89	16	18
23		Atrium	(11)		IVt	78(70.2-85.8)b	92(83.6-100.4)b	14	19
24		Sino-atrial node			IVt	56	57	1	19
25		Sino-atrial node		25	IVt	61	66	5	18
26		Sino-atrial node		30	IVt	66(51-74)	79(63-94)	13	8
27	Rat	Ventricle	(9)	128	IVt	83(65-101)b	101	18(2-34)b	20
28		Atrium	(8)	867	IVt	62(51-73)b	75.2(59.6-90.8)b	13.2(4.0-22.4)b	21
29	Sheep and calf	Purkinje fiber	60		IVt	98(91-110)	132	34(24-40)	22

30	Chick embryo	Ventricle		195	ISu	39.3(10-70)	53.5(13-100)	14	23
31		Atrium		44	ISu	29 2(10-41)	39.2(11-81)	10	23
32	Turtle	Ventricle			IVt	85	110	25	24
33		Atrium		10	ISu	56(50-63)	65(55-90)	9(2-30)	25
34	Frog	Ventricle	10	150	ISu,IVt	58.4(40-80)	74 2(50-110)	16	26
35		Ventricle	*10*	239	ISu,IVt	64.5(27-112)	77.2(30-132)	13	23,27
36		Ventricle	10	485	IVt	84.5(77-89)	102.5(95-112)	18.9(13-26)	28
37		Sinus venosus			IVt	(45-60)	(50-70)	(5-15)	29
38		Truncus arteriosus			ISu	95	125	30	12,13

/1/ Values in parentheses are for fiber diameters determined from formalin-fixed paraffin sections [30]. /2/ Technical difficulties encountered in measuring small fibers make it advisable to accept low values with caution.

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Part II: ACTION POTENTIAL CHARACTERISTICS OF SINGLE FIBERS

For a summary of conduction velocity, *see reference 21.* Determined with two intra- or extracellular recording electrodes. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Animal	Tissue Fiber	Total Duration[1] msec	Conduction Velocity m/sec	Upstroke Duration msec	Depolarization Maximum Rate v/sec	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Man	Ventricle	200				1
2	Cat	Ventricle	(200-400)				2
3		Atrium[2]	250	0.3		11.6	3
4		Papillary muscle[2]	100	0.96(0.9-1.0)[b]	1.1		4
5	Dog	Ventricle[2]	(300-500)	0.88(0.34-1.65)	2.0	150	2, 5
6		Atrium	(100-200)				6
7		Atrium[2], papillary muscle	250	1.0		>150	7
8		Purkinje fiber	(250-400)	2.5			8
9		Purkinje fiber[2]	300	2.0(1.3-3.2)	0.5	610	9
10		Sinus	300				6
11	Goat	Purkinje fiber[3]	300	2.2(1.7-2.7)	0.5	800	9
12	Guinea pig	Ventricle	(70-100)				10
13		Atrium	(100-150)				11, 12
14	Mouse	Atrium	30				13
15	Rabbit	Atrium	135				14
16		Atrium	150				15
17		*Sino-atrial node*	(200-300)				15
18		Sino-atrial node	189				14
19	Sheep and calf	Purkinje fiber	400				16
20	Chick embryo	Ventricle[4]	120(100-400)[b]				17
21		Atrium[4]	50(30-70)[b]				17
22	Turtle	Ventricle	(600-1400)				18
23		Atrium	(400-700)				18
24	Frog	Ventricle[5]		0.174	7.4	10	3, 19
25		Sinus venosus	(400-600)				20
26		Truncus arteriosus	560				11, 12

/1/ Conveys order of magnitude only, since this measurement varies *markedly with changes in frequency of contraction.* /2/ At 37-38°C. /3/ At 33.5°C. /4/ From 7-day-old embryo. /5/ At 18-19°C.

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Part III ELECTRICAL CONSTANTS OF SINGLE PURKINJE FIBERS

Determined with two intracellular electrodes. One electrode provided a polarizing pulse which was recorded by the other at various distances. A long (100 msec) square pulse of anodal current was used Abbreviations: λ = fiber space constant, R_m = membrane resistance, C_m = membrane capacity, T_m = membrane time constant, R_i = specific resistance of myoplasm, R_o = extracellular resistance. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	No. of Determinations	Fiber Diameter μ	Fiber Length mm	λ mm	R_m Ω sq cm	C_m μf/sq cm	T_m msec	R_i Ω cm	R_o Ω cm	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Goat	6	75 (53-104)	4.3 (3.0-6.4)	1.9 (1.2-2.5)	1940[1] (760-3380)	12.4 (9-29)	19.5 (18-39)	105 (52-190)	51	1
2	Sheep and calf	4	75		1.6[2]	1220 (480-2400)	11.3 (10.7-12.2)	13.8[2]	154 (81-240)	51	2

/1/ Falls to 20 sq m during action potential upstroke. /2/ C lculated.

Contributors (a) Hoffman, Brian F., (b) Brady, Allan J., (c) Weidmann, Silvio

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30. EFFECT OF pH ON THE HEART: DOG

	pH	Heart Rate beats/min	PR Interval sec	Depolarization QRS, sec	Repolarization Process: ST Segment	Repolarization Process: T Wave	QT_c[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Acid							
1	7.4[2]	150	0.09	0.04	-0.5	+1.3	0.35	1
2	6.2[3]	120	0.13	0.05	-3.5	+3.0	0.35	
	Alkaline							
3	7.4[2]	160	0.09	0.04	-0.5	+1.2	0.35	2
4	8.0[4]	100	0.11	0.04	-3.5	-4.0	0.35	

/1/ QT interval divided by the square root of the cycle length (Bazett's K). /2/ Normal /3/ Causes decrease in contractility and automaticity; death from cardiac arrest. /4/ Produces monophasic currents in animals and predisposes to cardiac arrhythmias; death usually from ventricular fibrillation.

Contributor: Gertler, Menard M.

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31. ELASTICITY OF THE ARTERIO-VENOUS SYSTEM: MAN, DOG

Intra-individual comparisons of elasticity at various levels of pressure (P) and volume (V) can be obtained by applying the following formula: elasticity in mm Hg/ml = $\frac{\Delta P \text{ mm Hg}}{\Delta V \text{ ml}}$. The resulting values when large indicate a high degree of stiffness (low extensibility).

Part I: AORTA

	Aorta	Specification	Pressure mm Hg	Elasticity	Reference
	(A)	(B)	(C)	(D)	(E)
			Man		
1	Thoracic, ml/cm length	20-24 yr	0	1.00	1
2			25	1.24	
3			50	1.55	
4			75	1.90	
5			100	2.40	
6			125	2.90	
7			150	3.35	
8			175	3.70	
9			200	3.95	
10			225	4.10	
11		29-31 yr	0	1.15	
12			25	1.40	
13			50	1.80	
14			75	2.25	
15			100	2.65	
16			125	2.90	
17			150	3.15	
18			175	3.30	
19			200	3.45	
20			225	3.55	
21		36-42 yr	0	1.25	
22			25	1.50	
23			50	1.95	
24			75	2.35	
25			100	2.65	
26			125	2.85	
27			150	3.00	
28			175	3.15	
29			200	3.25	
30			225	3.30	
31		47-52 yr	0	1.30	
32			25	1.65	
33			50	2.05	
34			75	2.35	
35			100	2.60	
36			125	2.80	
37			150	2.95	
38			175	3.05	
39			200	3.15	

	Aorta	Specification	Pressure mm Hg	Elasticity	Reference
	(A)	(B)	(C)	(D)	(E)
			Man (concluded)		
73	Abdominal, *ml/cm length* (concluded)	18 yr, 50 kg *(concluded)*	150	1.99	2
74			175	2.06	
75	Total, ml/cm length	18 yr, 50 kg	0	1.25	
76			25	1.64	
77			50	2.19	
78			75	2.94	
79			100	3.61	
80			125	3.97	
81			150	4.23	
82			175	4.37	
			Dog		
83	Arch, ml/cm length	14.5 kg	0	0.83	2
84			25	1.17	
85			50	1.57	
86			75	2.09	
87			100	2.57	
88			125	2.95	
89			150	3.23	
90			175	3.42	
91			200	3.58	
92	Thoracic, ml/cm length	14.5 kg	0	0.50	
93			25	0.56	
94			50	0.65	
95			75	0.77	
96			100	0.93	
97			125	1.07	
98			150	1.19	
99			175	1.27	
100			200	1.31	
101	Abdominal, ml/cm length	14.5 kg	0	0.36	
102			25	0.43	
103			50	0.50	
104			75	0.58	
105			100	0.65	
106			125	0.72	
107			150	0.77	
108			175	0.80	
109			200	0.82	

			225	3.20	
40		71-78 yr	0	1.75	
41			25	2.35	
42			50	2.75	
43			75	3.00	
44			100	3.15	
45			125	3.30	
46			150	3.35	
47			175	3.40	
48			200	3.45	
49			225	3.50	
50	Thoracic, ml/cm length	18 yr, 50 kg	0	1.02	2
51			25	1.23	
52			50	1.55	
53			75	1.98	
54			100	2.49	
55			125	2.91	
56			150	3.19	
57			175	3.27	
58	Arch, ml/cm length	18 yr, 50 kg	0	2.11	
59			25	2.96	
60			50	4.14	
61			75	5.78	
62			100	6.99	
63			125	7.50	
64			150	7.94	
65			175	8.13	
66	Abdominal, ml/cm length	18 yr, 50 kg	0	0.67	
67			25	0.88	
68			50	1.14	
69			75	1.43	
70			100	1.73	
71			125	1.87	
72					

110	Total, ml/cm length	14.5 kg	0	0.50	
111			25	0.61	
112			50	0.76	
113			75	0.93	
114			100	1.12	
115			125	1.27	
116			150	1.40	
117			175	1.48	
118			200	1.53	
119	3rd to 6th rib length, Δml	Aorta filled at rate of 100 ml/min	25	0.22	3
120			50	0.75	
121			75	1.33	
122			100	1.98	
123			125	2.55	
124			150	3.10	
125			175	3.55	
126			200	3.87	
127			225	4.12	
128		Aorta filled at rate of 10 ml/min	25	0.25	
129			50	0.80	
130			75	1.40	
131			100	2.05	
132			125	2.65	
133			150	3.20	
134			175	3.65	
135			200	4.00	
136			225	4.30	
137	Total, ml/entire length		25	20.5	4
138			50	24.0	
139			75	30.5	
140			100	35.5	
141			125	40.0	
142			150	42.5	

Contributors: (a) Haddy, Francis J., (b) Alexander, Robert S.

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Part II: VENOUS SYSTEM

	Component (A)	Pressure mm Hg (B)	Elasticity (C)	Reference (D)
	Man			
1	Common iliac vein, ml	0	0.60	1
2		1	2.25	
3		2	2.50	
4		3	2.70	
5		4	2.90	
6		5	3.10	
7		6	3.25	
8		7	3.40	
9		8	3.55	
10		9	3.70	
11		10	3.80	
12		11	3.90	
13	Internal mammary vein, ml	0	0.020	1
14		1	0.500	
15		2	0.540	
16		3	0.560	
17		4	0.570	
18		5	0.580	
19		6	0.590	
20		7	0.595	
21		8	0.600	
22		9	0.605	
23		10	0.610	
24		11	0.615	
25		12	0.620	
26		13	0.625	
	Dog			
27	Right atrium, ml	0	0.0	2
28		5	7.0	
29		10	12.0	
30		15	16.5	
31		20	20.0	
32		25	23.0	
33		30	26.0	
34	Left atrium, ml	0	0.0	
35		5	3.0	
36		10	5.0	
37		15	8.0	
38		20	9.0	
39		25	10.0	
40		30	10.5	
41	Inferior vena cava, ml	0	2.5	3
42		1	6.9	

	Component (A)	Pressure mm Hg (B)	Elasticity (C)	Reference (D)
	Dog (concluded)			
78	Mesenteric venous system filled at 100 ml/min, Δ ml (concluded)	20	2.70	5
79		22	2.90	
80		24	3.10	
81		26	3.30	
82		28	3.48	
83		30	3.65	
84		32	3.83	
85		34	4.03	
86		36	4.25	
87		38	4.50	
88		40	4.75	
89	Mesenteric venous system filled at 10 ml/min, Δ ml	4	0.00	
90		6	0.60	
91		8	1.18	
92		10	2.00	
93		12	3.00	
94		14	4.08	
95		16	5.15	
96	Pulmonary vascular bed immediately upon filling, Δ ml	5	20	6
97		10	40	
98		15	60	
99		20	75	
100		25	88	
101		30	104	
102		35	117	
103		40	131	
104		45	142	
105		50	153	
106		55	163	
107	Pulmonary vascular bed 5 sec after filling, Δ ml	5	20	
108		10	43	
109		15	63	
110		20	80	
111		25	94	
112		30	111	
113		35	126	
114		40	139	
115		45	154	
116		50	167	
117		55	180	
118	Pulmonary vascular bed immediately upon withdrawal, Δ ml	5	60	
119		10	87	
120		15	109	

		2	8.8	
43		3	9.7	
44		4	10.4	
45		5	10.8	
46		6	11.3	
47		7	11.6	
48		8	11.8	
49		9	12.1	
50		10	12.3	
51		11	12.5	
52		12	12.8	
53		13	13.0	
54		14	13.2	
55		15	13.4	
56		16	13.6	
57		0	0.00	4
58	Femoral venous system, Δml	2	0.95	
59		4	1.85	
60		6	2.70	
61		8	3.50	
62		10	4.25	
63		12	4.90	
64		14	5.40	
65		16	5.85	
66		18	6.20	
67		20	6.40	
68		22	6.50	
69		4	0.00	5
70	Mesenteric venous system filled at 100 ml/min. Δml	6	0.45	
71		8	0.95	
72		10	1.40	
73		12	1.70	
74		14	1.95	
75		16	2.20	
76		18	2.45	
77				
		20	127	
121		25	138	
122		30	148	
123		35	156	
124		40	162	
125		45	169	
126		50	176	
127		55	180	
128		5	4.0	6
129	Left atrium and pulmonary veins immediately upon filling. Δml	10	10.5	
130		15	16.0	
131		20	20.0	
132		25	23.0	
133		30	25.0	
134		35	26.5	
135		40	28.0	
136		45	29.0	
137		50	29.5	
138		5	4.5	
139	Left atrium and pulmonary veins 5 sec after filling, Δml	10	11.5	
140		15	17.0	
141		20	21.5	
142		25	24.0	
143		30	26.0	
144		35	27.5	
145		40	29.0	
146		45	29.5	
147		5	7.5	
148	Left atrium and pulmonary veins immediately upon withdrawal. Δml	10	15.5	
149		15	21.5	
150		20	24.5	
151		25	26.5	
152		30	28.0	
153		35	29.0	
154		40	29.5	
155				

Contributor: Haddy, Francis J.

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32. BLOOD VOLUMES

For a summary of blood volume methods and interpretations, see reference 24, Part I. Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I: MAN

Values for plasma and RBC volumes were obtained by various dilution methods. Unless otherwise indicated, Evans' blue dye (T-1824) was used to measure plasma volume, and red cells tagged with radioactive phosphorus (P^{32}) were used to measure RBC volume. Venous hematocrit values were obtained by centrifuging venous samples for 30 minutes at 3000 rpm and at a radius of 15 cm; values were not corrected for trapped plasma. Total blood volume was calculated from the two other values listed on the same line. Where blood volumes have been estimated directly from dilution with tagged red cells, it has been assumed that the venous RBC concentration represents the total body RBC concentration. Subjects were normal, unanesthetized adults of the white race, under average environmental temperature (22-28°C) and sea level barometric pressure conditions.

	Subjects: Sex (A)	Subjects: No. (B)	Venous Hematocrit % cells (C)	[illegible]olume [illegible]g	RBC Volume ml/kg (E)	Total Blood Volume ml/kg (F)	Reference (G)
1	Male	40		[illegible] 62.5)	29.8(21.5-36.3)[1]	77.7(63.8-97.0)	1
2		20	44.1(39.3-49.4)	[illegible] 56.5)		81.6(65.4-95.2)	2
3		49	44.7(36.0-51.8)[2]	[illegible] 58.2)		77.7(62.7-97.7)	3
4		11	47.2(42.0-53.0)[3]	[illegible] 48.2)		76.7(60.5-92.6)	4
5		31	44.1(34.9-49.0)[4]	[illegible] 61.8)[5]		74.2(60.0-96.0)	5
6		53	44.7[6]	[illegible] 56.5)		82.3(59.8-101.7)	6
7		51	45.0[6]	[illegible] 3)		85.1	7
8		32	42.6(37.9-49.2)[6]	[illegible]		82.1	8
9		30	46.3	[illegible] 55.9)			9
10		21		[illegible] 48.5)[7]			10
11		59					11
12		25			31.8(25.4-38.7)[8]		12
13		88				65.5(45.8-81.0)[8]	13
14		30		41.1	28.0	69.1	14
15		11		47.4	35.4	82.8	15
16	Female	20	39.8(37.1-41.9)	44.7(37.2-58.5)		74.3(63.0-97.5)	2
17		41	40.0(33.7-44.4)[2]	41.5(26.9-52.3)		66.1(46.3-85.4)	3
18		16	42(37-46)		27.0(21.1-32.7)	64.4(49.6-77.5)	16
19		35	39.2(34.5-43.8)[6]	48.2			17
20		30		41.5	21.6	63.1	14
21		4		44.8	27.5	72.3	15
22	Unspecified	13		47.1(39.7-52.2)	30.1(25.6-33.7)	76.4(66.5-83.1)	18
23		33	43.8(34.5-50.0)[3,6]	44.8(36.9-54.7)		81.3(59.2-103.7)	19
24		25	44.1(40.3-48.5)[6]	43.6(32.6-53.7)[5]		78.1(58.4-97.1)	20
25			44.1(40.3-48.5)[6]	45.4(32.3-54.2)		81.3(56.9-100.0)	
26			44.1(40.3-48.5)[6]		30.1(21.1-44.1)	68.3(49.3-91.8)	
27		10		41.1(31.6-48.5)[7]	30.3(23.7-42.1)[8]	71.4	21
28		21			36.0(30.2-42.2)[9]		22
29		45		39.6[5]		75.1[10]	23

/1/ RBC labelled with radioactive iron (Fe^{55} or Fe^{59}). /2/ Calculated from: $\frac{\text{reading of packed cells}}{\text{reading of fluid level - 2.0}}$. /3/ Tubes centrifuged until cells completely packed. /4/ Obtained from specific gravity of blood in copper sulfate solution. /5/ Plasma diluted with radioactive, iodinated, human serum albumin. /6/ Hematocrit corrected for trapped plasma by a factor of 0.96 or 0.95. /7/ Plasma diluted with radioactive chromium (Cr^{51}) in the form of chromic chlorid[illegible] /8/ RBC labelled with radioactive chromium (Cr^{51}) in the form of sodium chromate. /9/ g RBC/kg. /10/ Hematocrit corrected for trapped plasma by a facto[illegible] of 0.915.

Contributors: (a) Reynolds, Monica, (b) Brown, Ellen, (c) Burke, Jack D., (d) Hansard, Sam L., (e) Walcott, William W.

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Part II: MAMMALS OTHER THAN MAN

Values for plasma and RBC volumes were obtained by various dilution methods. Unless otherwise indicated, Evans' blue dye (T-1824) was used to measure plasma volume, and red cells tagged with radioactive phosphorus (P^{32}) were used to measure RBC volume. Venous hematocrit values were obtained by centrifuging venous samples for 30 minutes at 3000 rpm and at a radius of 15 cm; values were not corrected for trapped plasma. Total blood volume was calculated from the two other values listed on the same line. Where blood volumes have been estimated directly from dilution with tagged red cells, it has been assumed that the venous RBC concentration represents the total body RBC concentration. Subjects were normal, unanesthetized, adult animals of unspecified sex, unless otherwise indicated. Female animals were not pregnant or lactating, unless otherwise indicated.

	Animal (A)	No. of Subjects (B)	No. of Observations (C)	Venous Hematocrit % cells (D)	Plasma Volume ml/kg (E)	RBC Volume ml/kg (F)	Total Blood Volume ml/kg (G)	Reference (H)
	Primates							
1	Monkey	23	23	40.4(29-49)	46.7(31-63)		75.1(52-109)	1
2		20	20				60.9(49-71)[1]	2
	Carnivores							
3	Cat	52	73		47.7(34-56)			3
4		13	13		46.5(34.3-65.8)			4
5	Dog	39	39		53.8(31.7-83.6)	38.8(22.5-64.4)[2]	92.5(63.9-134.6)	5
6		10[3]	10		58.0(51.9-66.0)	42.9(35.8-64.8)	100.9(91.2-123.4)	6
7					51.8(47.2-56.8)[4]	42.9(35.8-64.8)	94.7(86.3-114.8)	
8		11	22		55.2(43.7-73.0)	39.0(28.0-55.0)	94.1(76.5-107.3)	7
9		13[3]	13		46.5(40.4-59.2)	27.1(20.4-38.7)[5]	73.6(66.6-79.8)	8
10		14	14		46.3(36.7-67.4)	37.2(18.8-66.3)[6]	83.8(58.9-115.7)	9
11			10				66.1(47-83)[7]	10
12		21	21				95(71-127)[8]	11
13		16[3]	16		42.0[9]	39.4[5]	81.4[10]	12
14		50	50	47.6(37.6-60.0)[11]	48.9(41.2-51.7)		92.7(84.0-97.3)	13
15		15	72		54.7(35-65)			14
16		106	106	42(28-52)	48.3(31.8-64.6)		83.2(60.0-107.5)	15
17		23	21		57.0(43.0-83.2)		100.0(79.6-121.0)[11]	16
18				43.2[11]	52.0		94.0	17

/1/ Calculated from hematocrit value and plasma volume measured with radioactive, iodinated, human serum albumin. /2/ RBC labelled with radioactive iron (Fe^{55} or Fe^{59}). /3/ Anesthetized. /4/ Plasma diluted with radioactive, iodinated, human plasma. /5/ RBC labelled with radioactive chromium (Cr^{51}) in the form of sodium chromate. /6/ RBC labelled with methemoglobin. /7/ Calculated from dilution with RBC labelled with Heinz granules. /8/ Calculated from dilution with RBC labelled with radioactive phosphorus (P^{32}). /9/ Calculated from RBC volume and hematocrit value. /10/ Calculated from sum of RBC volume and calculated plasma volume. /11/ Hematocrit corrected for trapped plasma by a factor of 0.96 or 0.95.

Part II: MAMMALS OTHER THAN MAN (Concluded)

	Animal	No. of Subjects	No. of Observations	Venous Hematocrit % cells	Plasma Volume ml/kg	RBC Volume ml/kg	Total Blood Volume ml/kg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Carnivores (concluded)				
19	Dog (concluded)		10[3]		47.0		89[12]	18
20		18	36	46.9(32.0-59.4)[11]	53.6(41.1-74.2)		97.5(78.2-123.0)	19
21		12	12	45.7(38.6-50.0)[11]	54.7(45.2-71.2)		102.0(79.0-127.5)	20
22		16[2]	16		51.6(37.1-70.8)			21
23					52.7(39.6-70.6)[13]			
				Rodents				
24	Guinea pig	10	10		38.6		72.0[14]	22
25		13	13		39.4(35.1-48.4)[15]		75.3(67.0-92.4)[16]	23
26	Mouse	3	11		48.8	29.0	77.7	24
27		5	5		57.4(55-63)			
28					49.2(41-54)[17]			
29	Rabbit	29	29		38.8(27.8-51.4)	16.8(13.7-25.5)	55.6(44.0-70.0)	25
30		71	71	35.2(28.6-41.0)[11]		17.2(13.4-22.8)	57.3(47.8-69.5)	
31		60	60		50		70[18]	26
32		39	67	38.8(27-48)	42.3(29-58)		69.8(50-93)	27
33		20	20	37.2(25.8-43.2)	43.5(35.1-49.8)		69.4(57.6-78.3)	28
34		15[3]	15		45		72[14]	18
35	Rat	35[3]	35		31.3	23.6	57.5	29
36		34[3]	34				63(46-74)[19]	30
37		22[3]	22	48.1(44-52)		23.2(18.9-25.5)[2]	49.6(41.9-54.0)	31
38		42[3, 20]	42	45.0(43-54)[21]		21.2(17.2-25.8)	45.2(34.6-59.5)	32
39		10[3]	100	49.2(44.0-55.4)[21]	27.4(24.6-31.1)		54.3(50.4-58.1)	33
				Artiodactyls				
40	Cattle, beef	4	4	41[11]			57	34
41	Dairy cows	10	10	32.4(30.3-34.9)[11]	38.8(36.3-40.6)		57.4(52.4-60.6)	35
42		3	3	40.9	36.6		62.0	36
43	Goat	20	20		55.9(42.6-75.1)	14.1(9.7-19.3)[5]	70.5(56.8-89.4)	37
44		30	30		53		70(57-82)	26
45	Sheep	6	6				58(50-73)[22]	38
46	3-yr-old ewes	4	4	34[11]			58	34
47	Swine, av wt = 52 kg	14	14	38[11]			59	34
48	Av wt = 50 kg	6[3]	6		41.9	27.5[2]	69.4	39
49	Av wt = 45 kg	4	4	39.1(30.3-43.1)[11]		25.9(20.2-29.0)	65(61-68)	40
				Perissodactyls				
50	Burro	16	16				65[23]	34
51		17	17			35	63	
52	Horse	2	2		51		72[18]	26
53	Light weight	6	6	43.3(37-56)	61.9(45.5-79.1)[24]	47.1(39.6-57.5)	109.6(94.3-136.0)	41
54	Heavy weight	4	4	40.3(37-46)	43.2(30.6-64.1)[24]	28.5(23.1-37.6)	71.7(56.7-101.7)	
				Marsupials				
55	Oposum	10	10		37.8(29.6-52.2)	19.2(14.2-29.2)[25]	57.0(44.5-69.8)[25]	42

/2/ RBC labelled with radioactive iron (Fe^{55} or Fe^{59}). /3/ Anesthetized. /5/ RBC labelled with radioactive chromium (Cr^{51}) in the form of sodium chromate. /11/ Hematocrit corrected for trapped plasma by a factor of 0.96 or 0.95. /12/ Calculated from plasma volume and arterial hematocrit value. /13/ Plasma diluted with Rose Bengal. /14/ Calculated from dye measured in whole hemolyzed cardiac blood. /15/ Calculated from blood volume and an

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average hematocrit of 47.6 obtained from 10 male guinea pigs /16/ Plasma diluted with radioactive, iodinated, rabbit globulin; blood volume calcul radioactivity of whole blood. /17/ Plasma diluted with radioactive, iodinated, mouse plasma. /18/ Calculated from plasma volume and hematocrit value. /19/ Calculated from laked cardiac blood after injection of RBC labelled with radioactive phosphorus (P^{32}). /20/ Two rats lactating. /21/ Cardiac blood used for hematocrit value. /22/ Calculated from sum of plasma volume and RBC volume. /23/ Calculated from plasma volume measured with radioactive iodinated burro plasma. /24/ Calculated from blood volume estimation. /25/ Hematocrit corrected for trapped plasma by a factor of 0.915.

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Part III: VERTEBRATES OTHER THAN MAMMALS; CRUSTACEANS AND MOLLUSKS

	Animal	No. and Sex	Method	Hematocrit % cells	Plasma Volume ml/100 g	RBC Volume ml/100 g	Total Blood Volume ml/100 g	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Birds				
1	Chicken	3♂	$Na_2Cr^{51}O_4$			2.1		1
2		4♀	$Na_2Cr^{51}O_4$			1.0		
3	Chicken, New Hampshire[1]	110♂	T-1824				9	2
4		113♀	T-1824				9	
5	Chicken, white Leghorn	3♂	T-1824	45	3.1		5.6	3
6		4♀	T-1824	30	4.4		6.3	
7	Chicks[2]	32	T-1824	30.5	6.6		9 6	4
8	Coot	2	T-1824	46	5.1		9.5	3
9	Duck	2♂	$Na_2Cr^{51}O_4$			3.0		1
10		2♀	$Na_2Cr^{51}O_4$			2 5		
11	Duck, dabbling, black, & mallard	7	T-1824	43	6 4		11.3	3

/1/ 6 weeks old to maturity. /2/ 13-35 days old.

32. BLOOD VOLUMES (Continued)

Part III: VERTEBRATES OTHER THAN MAMMALS; CRUSTACEANS AND MOLLUSKS (Concluded)

	Animal	No. and Sex	Method	Hematocrit % cells	Plasma Volume ml/100 g	RBC Volume ml/100 g	Total Blood Volume ml/100 g	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Birds (concluded)							
12	Duck, diving, redhead, and canvasback	6	T-1824	37	7.1		11.1	3
13	Duck, white Peking	42	I^{131} human serum albumin		6.55		10.2	5
14	Hawk, red-tailed[3]	3	T-1824	43	3.5		6.2	3
15	Loon, red-throated	1	T-1824	54	6.1		13.2	
16	Owl, great-horned	1	T-1824	43	3.4		6.4	
17	Pheasant, ring-necked	4♂	T-1824	30	4.5		6.7	
18		2♀	T-1824	33	3.2		4.8	
19	Pigeon	2♂	$Na_2Cr^{51}O_4$			3.2		1
20		2♀	$Na_2Cr^{51}O_4$			3.4		
21		6	T-1824	52	4.4		9.2	3
	Amphibians							
22	Frog (Rana pipiens)	10	T-1824	13.9[4]	7.0		8.2	6
23	Frog, bull (R. catesbiana)	2	T-1824	15.5[4]	8.0		9.5	6
	Fishes							
24	Bullhead, yellow (Ameiurus natalis)	6	T-1824	30.1[4]	1.25		1.8	6
25	Cod, ling (Ophiodon elongatus)	9	T-1824				2.5	7
26	Ratfish (Chimera colliaei)	2♀	T-1824	18[4]			2.6	7
	Crustaceans							
27	Crayfish (Cambarus virilis)	11	T-1824				25.1	6
	Mollusks							
28	Mussel, fresh-water (Lampsilis ventricosa, Amblema costata)	25	T-1824				9.5[5]	6

/3/ Immature. /4/ Cardiac blood. /5/ Per cent by body volume.

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Part IV: INSECTS

Blood volume varies according to sex, stage of development, age, nutrition, rearing status, method of blood extraction, coagulability, and method of volume determination. Method: A = assumed or calculated, C = chloride, D = dye, E = exsanguination, H = cell dilution, M = manganese dilution, R = C^{14} inulin. Unit of measurement. BW = body weight, live or fresh unless otherwise specified. Values in parentheses are ranges, estimate "b" or "c" as indicated by superscript (cf. Introduction)

	Order	Species	Stage	Method	Blood Volume: Value	Blood Volume: Unit of Measurement	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Neuroptera	Sialis lutaria (alder fly)	Larva	E	25	% BW	1
2	Blattaria	Blattella germanica (German roach)		A	20	% BW	2
3		Periplaneta americana (American roach)	Adult	E	(5-20)[c]	mg/insect	3
4					17	% BW	4
5			Nymph, ♂	D	19.6(18.8-20.4)[b]	% BW	5
6				C	20(16.3-23.7)[b]	% BW (individual)	
7					16.8(14.8-18.8)[b]	% BW (pooled)	
8				H	15.7(13.2-18.2)[b]	% BW	
9			Nymph, ♀	D	19.8(19.1-20.5)[b]	% BW	5
10				C	18.6(14.5-22.7)[b]	% BW (individual)	
11					19.5(17.2-21.8)[b]	% BW (pooled)	
12				H	16.8(12.3-21.3)[b]	% BW	
13			Adult, ♂	D	27.5(23.8-31.2)[b]	% BW	5
14				C	15.3(12.9-17.7)[b]	% BW	
15			Adult, ♀	D	20.9(18.8-23.0)[b]	% BW	5
16				C	16.9(11.9-21.9)[b]	% BW	
17		P. fuliginosa	Nymph to adult	H	(4.7-6.9)[c]	% BW	6
18	Orthoptera	Anabrus simplex (Mormon cricket)	Adult	E	(0.05-0.10)[c]	ml/insect	7
19		Locusta migratoria migratorioides (African migratory locust)	Nymph	E	<0.2	ml/insect	8
20			Adult	E	(0-1)[c]	cu mm/insect	8
21	Isoptera	"Termite queen"	Adult, ♀	E	17	ml/insect	9
22	Coleoptera	Dytiscus sp		E	0.1	ml/insect	10
23		Hydrophilus sp		E	0.3	ml/insect	10
24		Popillia japonica (Japanese beetle)	Larva	E	(0.9-25.4)[c]	% BW	11
25				M	40.9(38.5-43.3)[b]	% BW	11
26				E	0.03	ml/insect	12
27		Tenebrio molitor (meal worm)	Larva	D	10	% BW	13
28				C	0.22	ml/g BW	14
29	Lepidoptera	Agapema galbina	Pupa, ♂ and ♀	E	33	% BW (mean)	15
30		Bombyx mori (silkworm)	Larva	E	(0.15-0.22)[c]	ml/g BW	16
31					0.35	ml/insect	10
32					31.2(27.6-34.8)[b]	% BW	17
33					28.6(25.6-31.6)[b]	% BW (dry)	
34			Pupa	E	(0.11-0.31)[c]	ml/g BW	16
35					(0.09-0.35)[c]	ml/insect	10
36			Adult	E	0.05	ml/insect	10
37		Celerio euphorbiae (hawk moth)	Larva, feeding	E	18.6(16.2-21.0)[b]	% BW	18
38			Larva (prepupa)	E	(18.0-28.6)[c]	% BW	18
39			Pupa	E	(18.3-42.6)[c]	% BW	18
40					35	% BW	19
41					33	% BW (dry)	
42					(0.6-0.7)[c]	ml/insect	9

32. BLOOD VOLUMES (Concluded)

Part IV: INSECTS (Concluded)

	Order	Species	Stage	Method	Blood Volume: Value	Blood Volume: Unit of Measurement	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
43	Lepidoptera (concluded)	Celerio euphorbiae (hawk moth) (*concluded*)	Pupa, latent	E	(26.7-38.0)[c]	% BW	19
44			Pupa, "subitan"	E	(3-30)[c]	% BW	19
45			Adult, ♂	E	7.8(4.8-10.8)[b]	% BW	18
46			Adult, ♀	E	7.2(2.8-11.6)[b]	% BW	18
47		Galleria mellonella (bee moth)	Larva	E	41(36.6-45.4)[b]	% BW (dry)	17
48		Hyalophora cecropia (*cecropia* moth)	Pupa	E	0.25	ml/g BW	20
49		*Prodenia eridania* (*southern army worm*)	Larva	E	0.12(0.07-0.20)[c]	ml/insect	21
50				R	0.19	ml/insect	22
51	Hymenoptera	Apis mellifera (honeybee)	Larva	E	(25-30)[c]	% BW	23
52					0.04	g/insect	
53	Diptera	Aedes aegypti and Culex pipiens (mosquito)	Larva	E	(0.3-0.4)[c]	cu mm	24
54		Phormia regina (blowfly)	Larva		20	µL	25
55			Adult		(1-4)[c]	µL	25
56		Sarcophaga bullata (flesh fly)	Larva	D	(35.0-42.6)[c]	% BW	26
57			Pupa	D	(23.8-33.4)[c]	% BW	26

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33. CONCENTRATION OF BLOOD IN TISSUE: VERTEBRATES

Part I: *TOTAL BLOOD VOLUME*

Values (µL of blood per gram of wet tissue) are obtained from determination of hemoglobin or labelled *RBC*, and/or plasma volume. Where only one element was measured, it is assumed that the ratio of cell to plasma volume is the same in tissue and blood. Abbreviations: RBCM = red blood cell mass, PV = plasma volume.

	Animal	No. and Sex	Measured Element	Labelled Substance	Bone	Brain	Heart	Intestine	Kidney	Liver	Lung	Skeletal Muscle	Skin	Spleen	Testis	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
1	Cat[1]	2 or more	RBCM	Hemoglobin		30	84		93	52	147	27		195		1
2	Dog[1,2]	7	RBCM PV	Iron^{59} Iodine^{131}		11	66	41	81	147	301	11		510		2
3	Mouse[3]	9	PV	Iodine^{131}					250	350	400			190		3
4	Mouse[4,5]	9	PV	Iodine^{131}	110	30		90	340	360	490	30		170	60	4

5	Mouse[6]	12♂ 40♂	RBCM PV	Iron[59] Iodine[131]				48	117	234	616	45	30	179		5, 6
6	Rat[4]	4-14	RBCM PV	Hemoglobin Evans' blue			379[7]		278	178	379[7]			481		7
7	Rat[2, 8]	♂	PV	Evans' blue	45	11	60	28	92	99	111	4	20	86	6	8
8	Rat[6, 9]	10-17♂	RBCM PV	Iron[59] Iodine[131]	41	33	262	34	128	270	519	26	19	170	16	9
9	Chick[10, 11]	9-13♂	RBCM PV	Chromium[51] Iodine[131]				78	326	231	575	38		198		10-12
10	Chicken[12, 13]	7-9♂	RBCM PV	Chromium[51] Iodine[131]				103	481	542	563	9		386	20	10-12

/1/ Sacrificed with barbiturate. /2/ Blood permitted to ooze from tissue. /3/ Average hematocrit = 42.8. /4/ Sacrificed with ether. /5/ Adrenal, 30; long bones, 110; submaxillary gland, 110. /6/ Sacrificed by rapid immersion in liquid nitrogen. /7/ Heart and lungs combined. /8/ Stomach, 41.1; large intestine, 23.3. /9/ Adrenal, 238; pituitary, 93; seminal vesicle, 23; spinal cord, 25; submaxillary gland, 81; thyroid, 181. /10/ 3-4 days old. /11/ Proventriculus, 72.5. /12/ 6-8 months old. /13/ Proventriculus, 94.3.

Contributors: (a) Hansard, Sam L., (b) Klein, J. Raymond, (c) Stearner, S. Phyllis, (d) Everett, Newton B., (e) Friedman, J. J.

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Part II: RESIDUAL BLOOD VOLUME

In quantitative studies involving investigations of tissue distribution of blood-borne substances, a correction for residual blood in tissues may be essential. Specific studies based on whole-tissue extractions measure not only the substance in the cells of the tissue, but also that existing in the blood trapped within these tissues at the time of sampling. A knowledge of the proportion of the material in the tissue that is due to blood alone, provides a basis for an estimated correction. Values are µL of blood per gram of wet tissue, and are derived from labelled RBC content of tissue. Values in parentheses are ranges, estimate "a" (cf. Introduction).

	Animal	No. of Subjects	Labelling Substance	Adrenal	Heart	Kidney	Liver	Lung	Pancreas	Pituitary	Skeletal Muscle	Spleen	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
1	Cattle[1]	7	Phosphorus[32]	35(28-41)	32(22-44)	53(34-70)	78(60-104)	224(182-262)	30(22-46)	41	10(8-11)	331(221-394)	1
2	Sheep[1]	6	Phosphorus[32]	25(17-42)	55(44-63)	56(53-64)	68(66-103)	224(163-294)	32(21-40)	21	14(7-20)	348(330-368)	1
3	Swine[1]	10	Phosphorus[32]	50(36-63)	35(28-46)	74(53-111)	72(51-84)	251(229-282)	22(17-25)		9(7-12)	124(99-163)	1
4	Rat[2]	7	Iron[59]		42	49	47				4	166	2

/1/ Sacrificed by blow on head and bled for 5 minutes. /2/ Anesthetized with ether and bled to death.

Contributors: (a) Hansard, Sam L., (b) Klein, J. Raymond, (c) Stearner, S. Phyllis, (d) Everett, Newton B., (e) Friedman, J. J.

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34. CARDIAC FUNCTION VS AGE: MAN

Cardiac output determined by the dye-dilution method, unless otherwise indicated. Values in parentheses are ranges, estimate "b" unless otherwise indicated (cf. Introduction).

	Age yr	No. and Sex	Body Surface Area, sq m	Heart Rate beats/min	Stroke Volume ml/beat	Cardiac Output L/min	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	2-29 hr	10					2.5(0.9-3.7)[c]	1
2	12.4	5♂, 5♀	1.29			5.55[1]	4.30	2
3	23.6	9♂	1.75(1.67-1.83)	76.9(67.7-97.8)	85.6(73.4-97.8)	6.49(5.47-7.51)	3.72(3.16-4.28)	3
4	34.1	10♂	1.86(1.74-1.98)	71.1(64.9-78.5)	91.8(77.6-106.0)	[illegible]	[illegible]	3
5	43.3	11♂	1.81(1.73-1.89)	69.1(63.1-75.1)	78.3(68.9-87.7)	[illegible]	[illegible]	3
6	54.8	11♂	1.67(1.57-1.77)	69.8(64.2-75.4)	67.2(61.0-73.4)	[illegible]	[illegible]	3
7	65.4	10♂	1.67(1.55-1.79)	63.0(56.6-69.4)	69.5(59.7-79.3)	[illegible]	[illegible]	3
8	71.0	10♂					[illegible]	4
9	73.3	9♂	1.61(1.51-1.71)	65.8(58.6-73.0)	63.0(53.6-72.4)	4.05(3.55-4.55)	2.54(2.18-2.90)	3
10	82.0	7♂	1.64(1.50-1.78)	67.0(52.0-82.0)	60.1(49.9-70.3)	3.87(3.09-4.65)	2.36(1.90-2.80)	3

/1/ Determined by the Fick method.

Contributors: (a) Wade, O. L., (b) Shock, Nathan W.

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35. CARDIAC INDEX DETERMINED UNDER BASAL CONDITIONS: MAN

Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Method	No. of Observations	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)
1	Acetylene	51	2.21(1.85-2.77)	1
2		100	2.26(1.70-2.90)	2
3		15	3.44(2.65-5.80)[1]	3
4	Ballistocardiogram	20	3.35	4
5		16	3.48	5
6		50	6.21[1]	6
7		48	6.79(5.13-10.97)	7
8	Dye (Hamilton)	6	4.10(3.16-5.10)	8
9		5	3.69(2.29-5.25)	9
10		8	4.00(2.80-5.30)	10
11	Ethyl iodide	24	2.40(1.45-3.72)	11
12	Fick	30	3.31	12
13		10	3.16(2.00-4.32)[b]	13
14		6	3.87(2.59-4.80)	8
15		13	3.74(3.16-4.40)	14
16		6	3.80(2.00-5.60)[b]	15
17		5	3.32(2.23-4.41)	9
18		7	3.80(2.80-4.70)	16

/1/ Cardiac output, in liters per minute.

Contributor: Ferencz, Charlotte

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36. CARDIAC INDEX DETERMINED BY DIRECT FICK OR DYE METHOD: MAN

All subjects resting (supine), and free of cardiovascular disease. Values in parentheses are ranges, estimate "b" unless otherwise indicated (cf. Introduction).

	Age yr	No. and Sex	Condition	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)	(E)
			Direct Fick Method		
1	13->80	53,♀♂	Hospital patients	3.5(2.9-4.1)	1
2	15-35	6	Hospital patients	3.8(2.0-5.6)	2
3	17-49	2♂, 4♀	Normal	3.9(2.1-5.7)	3
4	17-64	33	Hospital patients	3.8(1.7-5.9)	4
5	18-57	11♂, 7♀	Hospital patients	3.2(1.5-4.9)	5
6	19-26	7♂	Normal	3.5(2.8-4.2)	6
7	19-59	3♂, 7♀	Hospital patients	3.8(2.5-5.1)	7
8	20-30	7♂	Normal	3.3(2.7-4.9)[1]	8
9	21-52	13♂	Normal	3.1(2.3-3.9)[2]	9
10	21-56	6♀	Hospital patients	3.0(1.7-4.3)[2]	9
11	21-57	11♂	Hospital patients	3.7(2.8-4 6)[2]	9
12	21-62	18,♂♀	Hospital convalescents	4.0(1.8-6.2)	10
13	22-35	9♂	Normal	3.1(1.9-4.3)[2]	11
14	23-38	13♂	Normal	3.7(2.9-4.5)	12
15	24-42	9♂	Normal	3.3(1.4-5.2)	13
16	39-63	3♂, 2♀	Normal	4.1(3.2-4.8)[c]	14
17	Unspecified	5	Normal	3.6(2.0-5.2)	15
18	Unspecified	8♂	4 normal, 4 with syphilis	4.2(2.9-5.5)	16
			Dye Method		
19	13->80	53,♂♀	Hospital patients	3.2(1.8-4.6)	1
20	14-68	17	Normal	3.3(2.1-4.5)	17
21	16-41	23 ♂, 1♀	Normal	3.6(2.4-4.8)	18
22	17-49	2♂, 4♀	Normal	4.1(2.7-5.5)	3
23	17-64	10♂	Normal	2.9(2.1-3.7)	4
24	18-39	22♂	Normal	3.6(2.4-4.8)	19
25	18-57	11♂, 7♀	Hospital patients	3.8(2.0-5.6)	5
26	19-86	67♂	Normal	2.9(1.3-4.5)	20
27	21-36	7♂	Normal	4.0(2.4-5.6)	21
28	21-42	8♂, 1♀	Normal	3.5(2.3-4.7)	18
29	21-55	2♂, 8♀	Normal	3.5(2.4-4.6)	22
30	22-26	10♀	Normal	3.5(1.9-5.1)	19
31	26-69	5♂	Normal	3.7(1.5-5.9)	23
32	28-36	7♂, 2♀	Normal	3.5(2.2-4.8)	24
33	30-40	12♂	Normal	3.6(2.2-5.0)	25
34	39-63	6♂, 4♀	Normal	4.1(2.4-5.8)	26
35	40-57	12♂	Normal	3.3(1.6-5 0)	27
36	Unspecified	9	Normal	3.3(2.3-4.3)	28
37	Unspecified	8	Normal	3.9(3.4-4.4)	29

/1/ Oxygen uptake not measured at time blood samples taken. /2/ Right atrial blood samples.

Contributor: Wade, O. L.

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37. CARDIAC INDEX VS O_2 UPTAKE, AT REST AND DURING EXERCISE: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Age yr	No. and Sex	Body Surface Area sq m	Method	Condition	O_2 Uptake ml/min/sq m	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Young adults	3♂	1.82(1.73-1.93)	Fick	Rest	155(132-164)	3.3(2.9-3.7)	1
2					Exercise	695(373-1153)	7.8(5.1-10.4)	
3	23(15-35)	8[1]		Fick	Rest	157(115-193)	4.2(2.6-5.7)	2
4					Exercise	315(254-398)	6.1(4.2-9.7)	
5	24.5(20-29)	3♂[2], 1♀[2]	1.84(1.54-1.99)	Fick	Rest	132(120-150)	4.32(3.37-5.20)	3
6					Exercise	295(253-339)[3]	5.25(4.06-6.14)[3]	
7	25(18-39)	23♂, 10♀	1.81[4]	Dye	Rest		3.59(2.16-5.11)[5]	4
8					Exercise	670[4]	6.41(4.03-14.90)[6]	
9	29(24-39)	9♂	1.87(1.76-2.10)	Fick	Rest	135(103-169)[7]	3.3(2.2-4.4)[7]	5
10					Exercise	247(208-302)[8]	5.0(4.4-5.8)[8]	
11	31(26-36)	3♂	1.83(1.78-1.87)	Fick	Rest	126(111-147)	3.27(2.62-3.83)	6
12					Exercise	609(269-912)	6.67(4.36-9.12)	
13	32(21-42)	8♂, 1♀	1.86(1.45-2.16)	Dye	Rest	154(124-203)	3.45(2.72-4.40)	7
14					Exercise	473(301-582)	5.31(3.14-8.05)	
15	32(25-49)	3♂[2], 1♀[2]	1.90(1.52-2.13)	Fick	Rest	144(142-146)	4.20(3.83-4.82)	3
16					Exercise	398(362-432)[9]	6.00(5.49-6.47)[9]	
17	33(27-42)	3♂[2], 1♀[2]	1.82(1.54-2.06)	Fick	Rest	145(129-160)	4.64(3.51-5.77)	3
18					Exercise	564(517-610)[10]	6.70(6.39-7.06)[10]	
19	34(26-52)	3♂[2], 1♀[2]	1.93(1.57-2.23)	Fick	Rest	137(124-155)	4.51(3.75-5.09)	3
20					Exercise	1047(935-1163)[11]	9.19(8.31-10.47)[11]	
21	Unspecified	7[12]	1.74(1.46-1.96)	Fick	Rest	137(106-169)	3.8(2.8-4.7)	8
22					Exercise	417(231-725)	5.5(4.4-6.9)	

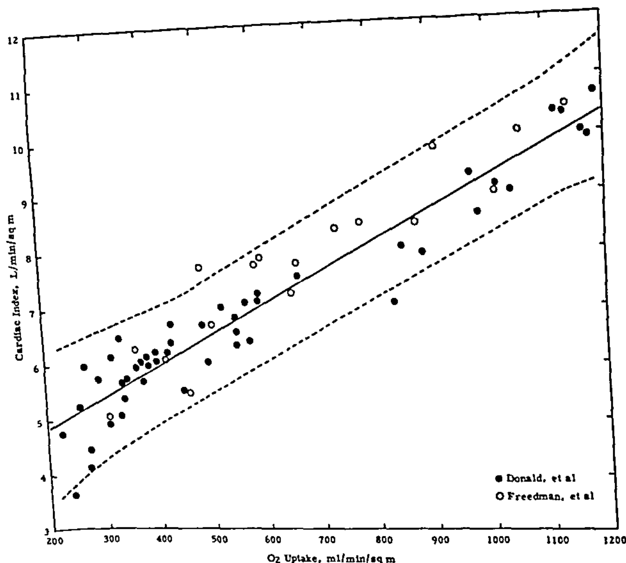
1/ Hospital patients with normal cardiovascular system. /2/ Subjects during rest apprehensive about impending exercise tests. /3/ Work level = 98 kg-m/min. /4/ Approximate value. /5/ 32 observations. /6/ 30 observations. /7/ 9 observations. /8/ 8 observations. /9/ Work level = 199 kg-m/min. /10/ Work level = 358 kg-m/min. /11/ Work level = 743 kg-m/min. /12/ 5 normal subjects, 1 with asymptomatic syphilis, and 1 with asymptomatic apical systolic murmur.

Contributors (a) Wade, O. L., (b) Shock, Nathan W.

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38. CARDIAC INDEX VS O_2 UPTAKE, DURING EXERCISE: MAN

Values for 16 normal subjects, plotted for the 3rd, 4th, and 5th minutes of exercise (data of Donald, et al [1]), and for 3 subjects at different levels of exercise (data of Freedman, et al [2]). Solid line represents the regression line of the data, and broken lines the 95% range. Cardiac index = 3.70 + 0.00553 oxygen uptake.



Contributor: Wade, O. L.

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37. CARDIAC INDEX VS O_2 UPTAKE, AT REST AND DURING EXERCISE: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Age yr	No. and Sex	Body Surface Area sq m	Method	Condition	O_2 Uptake ml/min/sq m	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Young adults	3♂	1.82(1.73-1.93)	Fick	Rest	155(132-164)	3.3(2.9-3.7)	1
2					Exercise	695(373-1153)	7.8(5.1-10.4)	
3	23(15-35)	8[1]		Fick	Rest	157(115-193)	4.2(2.6-5.7)	2
4					*Exercise*	*315(254-398)*	*6.1(4.2-9.7)*	
5	24.5(20-29)	3♂[2], 1♀[2]	1.84(1.54-1.99)	Fick	Rest	132(120-150)	4.32(3.37-5.20)	3
6					Exercise	295(253-339)[3]	5.25(4.06-6.14)[3]	
7	25(18-39)	23♂, 10♀	1.81[4]	Dye	Rest		3.59(2.16-5.11)[5]	4
8					Exercise	670[4]	6.41(4.03-14.90)[6]	
9	29(24-39)	9♂	1.87(1.76-2.10)	Fick	Rest	135(103-169)[7]	3.3(2.2-4.4)[7]	5
10					Exercise	247(208-302)[8]	5.0(4.4-5.8)[8]	
11	31(26-36)	3♂	1.83(1.78-1.87)	Fick	Rest	126(111-147)	3.27(2.62-3.83)	6
12					Exercise	609(269-912)	6.67(4.36-9.12)	
13	32(21-42)	8♂, 1♀	1.86(1.45-2.16)	Dye	Rest	154(124-203)	3.45(2.72-4.40)	7
14					Exercise	473(301-582)	5.31(3.14-8.05)	
15	32(25-49)	3♂[2], 1♀[2]	1.90(1.52-2.13)	Fick	Rest	144(142-146)	4.20(3.83-4.82)	3
16					Exercise	398(362-432)[9]	6.00(5.49-6.47)[9]	
17	33(27-42)	3♂[2], 1♀[2]	1.82(1.54-2.06)	Fick	Rest	145(129-160)	4.64(3.51-5.77)	3
18					Exercise	564(517-610)[10]	6.70(6.39-7.06)[10]	
19	34(26-52)	3♂[2], 1♀[2]	1.93(1.57-2.23)	Fick	Rest	137(124-155)	4.51(3.75-5.09)	3
20					Exercise	1047(935-1163)[11]	9.19(8.31-10.47)[11]	
21	Unspecified	7[12]	1.74(1.46-1.96)	Fick	Rest	137(106-169)	3.8(2.8-4.7)	8
22					Exercise	417(231-725)	5.5(4.4-6.9)	

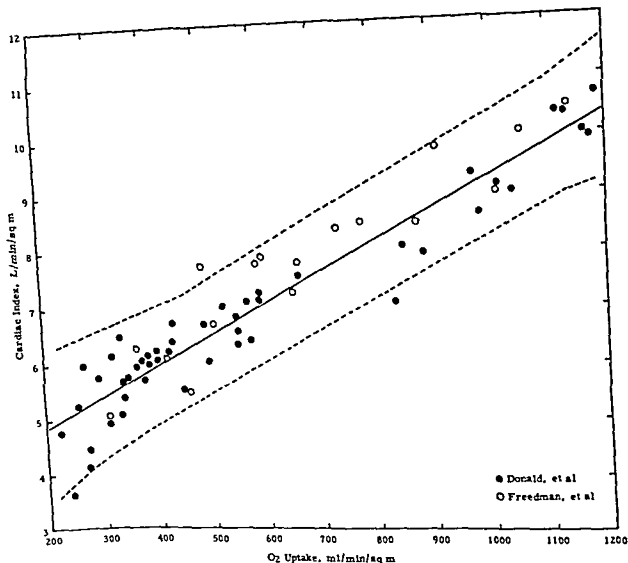
/1/ Hospital patients with normal cardiovascular system. /2/ Subjects during rest apprehensive about impending exercise tests. /3/ Work level = 98 kg-m/min. /4/ Approximate value. /5/ 32 observations. /6/ 30 observations. /7/ 9 observations. /8/ 8 observations. /9/ Work level = 199 kg-m/min. /10/ Work level = 358 kg-m/min. /11/ Work level = 743 kg-m/min. /12/ 5 normal subjects, 1 with asymptomatic syphilis, and 1 with asymptomatic apical systolic murmur.

Contributors: (a) Wade, O. L., (b) Shock, Nathan W.

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38. CARDIAC INDEX VS O_2 UPTAKE, DURING EXERCISE: MAN

Values for 16 normal subjects, plotted for the 3rd, 4th, and 5th minutes of *exercise* (data of Donald, et al [1]), and for 3 subjects at different levels of exercise (data of Freedman, et al [2]). Solid line represents the regression line of the data, and *broken* lines the 95% range. Cardiac index = 3.70 + 0.00553 oxygen uptake.

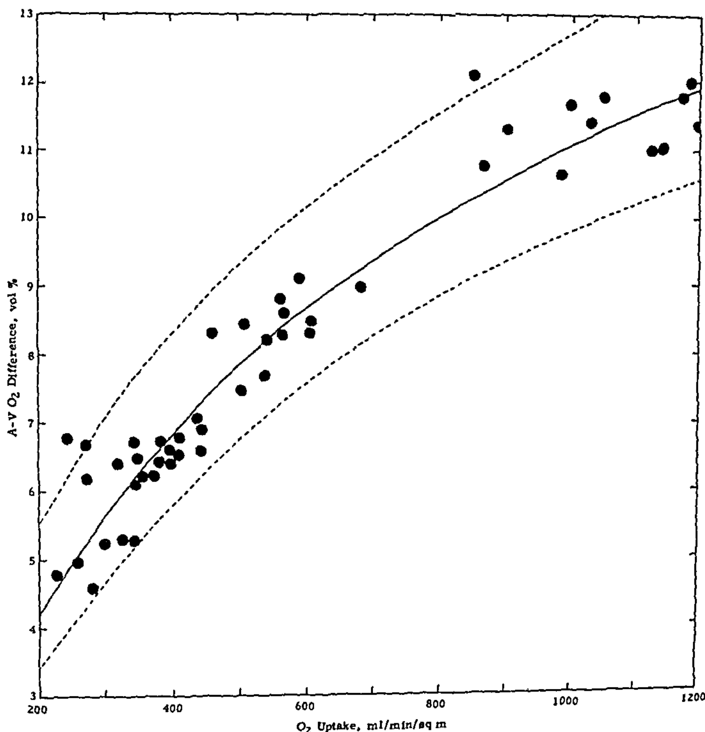


Contributor: Wade, O. L.

References: [1] Donald, K. W., J. M. Bishop, G. Cumming, and O. L. Wade. 1955. Clin. Sc., Lond. 14:37.
[2] Freedman, M. E., G. L. Snider, P. Brostoff, S. Kimelblot, and L. N. Katz. 1955. J. Appl. Physiol. 8:37.

39. O_2 UPTAKE VS ARTERIO-VENOUS O_2 DIFFERENCE, DURING EXERCISE: MAN

Values for 16 normal subjects plotted for the 3rd, 4th, and 5th minutes of exercise. Solid line represents the regression line of the data, and broken lines the 95% range. Regression line formula: A-V O_2 content difference, ml/100 ml (normal temperature and pressure) = $\frac{18.77 \times O_2 \text{ uptake, ml/min}}{O_2 \text{ uptake, ml/min} + 694.44}$.



Contributor: Wade, O. L.

Reference: Donald, K. W., J. M. Bishop, G. Cumming, and O. L. Wade. 1955 Clin. Sc., Lond. 14:37.

40. CARDIAC OUTPUT VS O_2 CONSUMPTION, DURING EXERCISE: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Exercise[1] kg-m/min	Weight kg	Body Surface Area, sq m	Method	O_2 Consumption L/min	Cardiac Output L/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	0 (Basal)	65	1.76	Acetylene	0.230(0.158-0.300)	3.87(2.96-4.61)	1, 2
2	0 (Basal)	65	1.77	Direct Fick	0.244(0.167-0.277)	5.51(3.80-7.30)	3
3	0 (Sitting)		1.73	Direct Fick	0.236(0.184-0.298)	6.6(4.7-8.3)	4
4	102	65	1.78[2]	Indirect Fick-CO_2	0.630(0.621-0.638)	8.8	5
5	264	65	1.78[2]	Indirect Fick-CO_2	0.865(0.839-0.891)	11.3(10.9-11.7)	5
6	525	65	1.78[2]	Indirect Fick-CO_2	1.369(1.348-1.390)	14.1(13.8-14.4)	5
7	725	65	1.78[2]	Indirect Fick-CO_2	1.814(1.653-1.974)	17.1(15.5-18.7)	5
8	840	64	1.75	Acetylene	2.08(2.05-2.10)	19.2(19.0-19.4)	6
9	960	72	1.92	Acetylene	[illegible]	22.1(20.6-23.8)	6
10	1200	75	1.98	Acetylene	[illegible]	[illegible]	6
11	1440	75	1.98	Acetylene	[illegible]	[illegible]	6
12	1680	75	1.98	Acetylene	[illegible]	[illegible]	6

/1/ Bicycle ergometer. /2/ Surface area = 0.11 x $Wt^{2/3}$.

Contributor: Barger, A. Clifford

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41. CARDIAC OUTPUT VS TEMPERATURE: MAN, DOG

Stroke volume varies according to the alteration in total circulation effected by a particular method of raising body temperature. The hot bath technique produces large peripheral dilatation, and, if blood pressure is maintained, an increase in cardiac output will occur. However, in the early stages of a fever induced by intravenous pyrogens, the heart rate increases but there is intense peripheral vasoconstriction, with no change or even diminution in cardiac output. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	Environment	Body Temperature °C	Stroke Volume ml/beat	Cardiac Output L/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Man[1]	Cold room, 0°C		72	4.2[2]	1
2		Cool room, 20°C		72	4.2[2]	
3		Hot room, 36°C		70	4.7[2]	
4		Hot room, 45°C		65	5.5[2]	
5	Man	24°C	36	133	8.5[3]	2
6		Hot bath, 47°C	40	151	15.9[3]	
7	Man[4]	Comfortable	33.1(32.9-33.8)		5.0(2.2-9.6)[5]	3
8		Hot, humid room	36.4(35.2-37.5)		20.2(3.5-36.6)[5]	
9	Man[6]	Comfortable	32.6(29.0-34.2)		5.1(2.3-7.1)[5]	3
10		Hot, humid room	35.7(34.4-36.2)		10.0(4.1-15.0)[5]	
11	Man[7]	Cool room, 15°C	36.7	39.6	2.38	4
12		Cool room, 22°C	36.7	42.2	2.80	
13		Hot room, 30°C	36.7	81.1	5.10	
14		Hot room, 40°C	36.7	108.1	7.85	
15		Hot room, 50°C	38.0	95.0	11.50	
16	Dog[8]	Cold room, 11°C	20	20.3	0.60	5
17		Cold room, 11°C	25	16.8	0.95	
18		Cold room, 11°C	30	16.6	1.52	
19		Cold room, 11°C	35	16.5	2.33	
20		Cold room, 11°C	38	20.5	2.99	
21	Dog[9]	Ice water	20	16.7	0.47	5
22		Ice water	25	13.5	0.84	
23		Ice water	30	12.8	1.26	
24		Ice water	35	12.1	1.55	
25		Ice water	38	9.9	1.34	

/1/ 1 subject *only*. /2/ Determined by acetylene method. /3/ Determined by ethyl-iodide method. /4/ 3 normal subjects /5/ Determined by Fick method. /6/ 4 patients with congestive cardiac failure. /7/ Single observations on 1 subject; age, 19 yr, weight, 71.5 kg, height, 180 cm. /8/ Anesthetized animals; average weight, 24.6 kg. 5 observations for each entry. /9/ Anesthetized animals, average weight, 10.5 kg; 13 observations for each entry.

Contributors. (a) Cooper, K. E., (b) Blasius, W., (c) Wade, O. L.

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Part I: MAN

Abbreviations: A = acetylene, B = ballistocardiogram, C = catheterization (Fick), D = dye (Hamilton), E = ethyl iodide, Hb = hemoglobin. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Condition	Subjects, No. and Sex	Age yr	Method	Cardiac Output L/min	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Anemia; Hb = 4.87(1.9-10.5) g	8♂, 10♀[1]	57(23-84)	C	9.22(6.9-14.3)		1
2	Anemia; Hb = 7.03(2.4-13.0) g	7♂, 10♀[2]	32.5(17-67)	C	8.08(3.9-13.6)	4.98(2.5-8.3)	2
3	Anemia; Hb = 7.87(5.8-10.8) g	11♂, 1♀[3]	22.5(12-39)	C	9.34(6.5-14.5)	6.06(5.1-7.5)	3
4	Anemia; Hb = 5.56(4.4-7.8) g	1♂, 10♀[4]	46.5(22-73)	C	8.45(5.9-13.4)	5.37(4.0-8.8)	4
5	Anemia; Hb = >7 g	10[5]	38(17-67)	C		3.60(2.5-5.1)	2
6	Anemia; Hb = <7 g	14[5]	34(19-67)	C		5.70(2.9-8.3)	
7	Anemia, rest	10♂, 1♀	22(12-39)	C		6.17(5.1-7.5)	3
8	Anemia, exercise; O_2 uptake = 250(194-304) ml/sq m	10♂, 1♀	22(12-39)	C		8.25(6.1-10.0)	
9	Anemia, rest	1♂, 10♀	46.5(22-73)	C		5.40(4.0-8.8)	4
10	Anemia, exercise; O_2 uptake = 410(210-579) ml/sq m	1♂, 10♀	46.5(22-73)	C		8.20(5.2-13.1)	
11	Anemia	5[5]		E		2.64(1.55-3.80)	5
12	Anoxemia; arterial O_2 saturation = 70%	16[5]		B		4.97	6
13	Anoxia (acute), 10% O_2 in N_2	5♂	(23-47)	C	5.20[6]		7
14	Anxiety	5♂[7]		C		5.5	8
15		12♂[8], 4♀[8]	31(21-52)	C		4.4(3.37-5.77)	9
16	Arrhythmia	8[5]		E		1.78(1.12-2.62)	5
17	Arteriosclerosis	10♂	71(62-77)	D		2.67(2.2-3.2)	10
18	Arterio-venous aneurysms	6♂	Young soldiers	C	7.4(4.8-9.2)	4.16(2.70-5.15)	11
19		2	28(20-36)	C	14.6(13.8-15.4)	7.56(7.17-8.14)	4
20		11	29(19-51)	C	11.1(6.4-16.0)		12
21		14		D		5.69(4.43-8.44)	13
22	Beriberi, alcoholic	1♂	29	C		7.8[9]; 4.2[10]	14
23		1♀	28	C		6.09[9]; 4.6[10]	15
24	Beriberi, alcoholic edematous	1♂	35	C	11.8[9]; 5.4[10]		16
25	Beriberi, occidental	1		C		4.3[9], 2.5[10]	17
26		1		C		7.2[9]; 2.7[10]	
27	[illegible]	8♂, 3♀	44(34-57)	D		4.27(2.76-6.08)	18
[illegible]		4♂, 2♀	46(39-57)	D		4.46(3.53-7.72)	19
[illegible]		6♂, 2♀	50(38-64)	D		5.33(3.24-11.20)	18
[illegible]		3♂, 1♀	38(16-51)	D		4.89(4.33-5.72)	19
[illegible]		8[5]		C		2.87(2.1-3.7)	20
[illegible]		6[5]		C		2.96(1.31-4.17)	21
33		6[5]		D		2.93(1.31-4 70)	22
34	Coronary arterial disease	11		B		2.89	6
35		8		E		2.76(1.29-5.20)	5
36	Fatty liver	3♂	43(41-45)	D		4.76(3.57-5.88)	18
37	Hypertension	12[5]		E		2.35(1.27-3.95)	5
38		3[5]		C		4.95(4.03-6.70)	21
39		3[5]		D		5.31(3.34-8.25)	
40		18[5]		C		3.23(1.85-5.91)	22
41		18[5]		D		3.31(2.00-5.50)	
42		5[5]		D		3.2(2.5-3.7)	23
43	Hyperthyroidism	3♂, 11♀	34(17-55)	C		5.24(3.3-6 3)	24
44		5♂, 5♀	34(12-59)	C		5.87(3.9-7.3)	
45	Hyperthyroidism, rest	2♂, 3♀	39(21-62)	C		6.36(5.44-8.39)	4
46	Hyperthyroidism, exercise; O_2 uptake = 672(474-1012) ml/sq m	2♂, 3♀	39(21-62)	C		9.76(6.8-12.6)	
47	Mitral insufficiency	11[5]		C		1.91(1.85-2.50)	25
48	Mitral lesion	12[5]		C		3.4(2.11-4.64)	22
49		12[5]		D		3.45(2.36-4.69)	
50	Mitral stenosis	7[5]		C		3.44(2.4-5 2)	20
51		18[5]		C		2.33(1.49-3.48)	25
52	Myocardial infarction	13[5]		D		2.7(1.5-4.7)	23

/1/ 6 acute, 5 chronic, 7 chronic with cardiac failure. /2/ 10 with iron deficiency, 4 with pernicious anemia, 2 with sickle cell anemia, 1 with aplastic anemia. /3/ 10 with sickle cell anemia, 1 with sickle cell anemia and cor pulmonale, 1 with sickle cell anemia and rheumatic fever. /4/ 7 with iron deficiency, 2 with pernicious anemia, 2 macrocytic. /5/ Number of observations. /6/ Breathing air: cardiac output, 5.74 L/min. /7/ Pulse rate exceeding 82 beats/min and metabolic rate elevated 10% above basal level. /8/ Apprehensive at prospect of exercising with catheters in heart. /9/ Before treatment. /10/ After treatment.

42. EFFECT OF VARIOUS CONDITIONS ON CARDIAC OUTPUT: MAMMALS (Continued)

Part I: MAN (Concluded)

	Condition	Subjects, No. and Sex	Age yr	Method	Cardiac Output L/min	Cardiac Index L/min/sq m	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
53	Myocardial infarction (acute), without shock	8♂, 1♀	57(51-66)	D		2.4(1.3-2.9)	30
54	Myocardial infarction (acute), with shock	5♂, 2♀	62(48-80)	D		1.6(1.3-2.2)	
55	Oxygen, 100%	16[5]		B		3.34	6
56	Paget's disease	6♂, 7♀	67(56-74)	C	6.74(3.7-13.3)		26
57		2	(54-55)	C	5.45(5.18-5.72)	3.47(3.27-3.66)	27
[illegible]	[illegible]	[illegible]	[illegible]	C	[illegible]	[illegible]	28
	[illegible] 142(116-168)^b L/min/sq m						
62	Pregnancy, 36-40 wk, O_2 uptake = 150(130-170)^b L/min/sq m	11♀	22.3(17-29)	C	5.53(4.09-6.97)^b	3.44(2.56-4.32)^b	
63	Pulmonary disease	5[5]		C		3.86(3.4-5.5)	20
64		10[5]		C		3.92(1.98-6.50)	21
65		10[5]		D		4.21(1.59-6.00)	21
66		2[5]		C		3.96(3.20-4.73)	22
67		2[5]		D		3.98(3.78-4.19)	22
68	Shock, mild	4[5]		C		2.46(2.18-2.71)	29
69	Sitting, legs outstretched	17♂[11], 19♀[11]	37(19-59)	C	5.57(2.45-11.19)		30
70	Supine	17♂[11], 19♀[11]	37(19-59)	C	5.93(2.43-11.38)		
71	Standing	15[5]		A	3.03(2.86-4.88)		31
72	Tilting, 70°	6[5]		C		2.7(2.0-3.9)	8
73	Trauma (skeletal), moderate	4[5]		C		2.06(1.30-3.01)	29

/5/ Number of observations /11/ Normal subjects and hospital patients.

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Part II: MAMMALS OTHER THAN MAN

Condition or Activity: U = urethane, M = morphine; B = butallylonal; Bt = barbiturate, P = sodium pentobarbital. Method. F = Direct Fick; W = Wetterer; R = Rotameter, NaCl = Stewart's NaCl; B-R = Broemser-Ranke. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Animal	No. of Subjects	Weight[1] kg	Body Surface Area, sq m	Condition or Activity	Method	O_2 Consumption L/min	Cardiac Output L/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Cat	10			Anesthetized (U)	F		0.332(0.127-0.537)[b]	1
2		5			Anesthetized (U)	F		(0.225-0.431)	2
3			4.1		Basal, anesthetized (U)	W		0.587	3-5
4	Dog		6 4	0.39[2]	Basal, anesthetized (M)	F	0.057(0.042-0.068)	1.12(0.65-1.57)	6-8
5		3	11.8		Basal, anesthetized (B)	W		1.13(0.81-1.58)	3,4,9
6		10			Anesthetized (M + Bt)	F		1.01(0.672-1.44)	10
7		10			Anesthetized (M + Bt)	R		0.994(0.668-1.46)	10
8			14.4	0.66[2]	Anesthetized (M + Bt)	NaCl		1.82(1.14-2.50)[b]	11
9			18.5	0.78[2]	Anesthetized (M + Bt)	NaCl		2.24(1.26-3.22)[b]	11
10			23.9	0.93[2]	Anesthetized (M + Bt)	NaCl		2.66(2.00-3.32)[b]	11
11		5[3]	16.1	0.71	Basal	F	0.106(0.063-0.184)	2.21(1.20-3.84)	12
12		2	15.0	0.68	Shivering due to cold water immersion	F	0.234(0.232-0.236)	4 49(3.66-5.31)	12
13			21.6	0.87[2]	Sitting or standing	F	0.206(0.150-0.245)	3.30(1.8-4.3)	13
14					[illegible]	[illegible]	[illegible]	[illegible]	
15			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
16					[illegible]	[illegible]	[illegible]	[illegible]	
17					[illegible]	[illegible]	[illegible]	[illegible]	
18					[illegible] 10°	[illegible]	[illegible]	[illegible]	
19					Treadmill, 5 mi/hr, 10°	F	1.402(1.380-1.420)	12.15(12.1-12.2)[4]	
20	Ferret	10	0.91		Anesthetized (Bt)	F		0.139(0.082-0.200)	14
21	Goat	21	23.7	0.91[5]	Basal	F	0.176(0 078-0.329)	3 1(1.37-5.60)	15
22	Horse	1	283.0	4.30[6]	Standing	F	1.364	18.8	16
23					Treadmill, 47 6 m/min, 0°	F	2.965	31.4	
24					Treadmill, 42.3 m/min, 8°	F	3.084	37.2	
25		1	342.0	4 90[6]	Standing	F	2.480	24.0	
26					Treadmill, 56.9 m/min, 6.5°	F	4 414(4.315-4.513)	53.1(46.6-59 5)	
27	Rabbit	8	3.2	0.21[7]	Anesthetized	F	0.021(0.014-0.028)	0.35(0.26-0.48)	17
28		38	2.1		Unanesthetized or lightly anesthetized	F		0.25(0.12-0.38)	18
29		3	4.6		Anesthetized (U)	W		0.527(0.284-0 763)	3,4,9
30		4	4.6		Anesthetized (U)	B-R		0.232(0.162-0.398)	19-21
31	Rat[8]	52	0.18	0.03[9]	Anesthetized (P)	F		0.047(0.015-0.079)	22

/1/ Average. /2/ Body surface area = $0.112 \times Wt^{2/3}$. /3/ 3 dogs pregnant during part of study. /4/ Average for 2-4 experiments on same dog. /5/ Body surface area = $0.11 \times Wt^{2/3}$. /6/ Body surface area = $0.10 \times Wt^{2/3}$. /7/ Body surface area = $0.098 \times Wt^{2/3}$. /8/ At altitude of 1 mile. /9/ Body surface area = $0.091 \times Wt^{2/3}$.

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43. HEART RATE. VERTEBRATES

Heart rate varies with species, sex, age, size, environment, and temperature. Values in parentheses are ranges, estimate "e" (cf. *Introduction*).

Part I: MAMMALS

	Species (A)	Weight g (B)	Heart Rate beats/min (C)	Reference (D)
1	Ass (*Equus asinus*)	400,000	(40-56)	1
2			(45-50)	1
3	Badger (*Taxidae taxus*)		138(128-144)	e
4	Bat (*Pipistrellus pipistrellus*)	4.3	660	2
5		4.3	30[1]	2
6	Bat (*Plecotus auritus*)	9.4	750(600-900)	1,2
7		9.4	76[1]	2
8	Beaver (*Castor canadensis*)		140	3
9			10[2]	3
10	Camel (*Camelus bactrianus*)		(25-32)	1
11	Cat (*Felis domesticus*)		(120-140)	1
12			(110-130)	4,5
13		2500	(116-128)	4,6
14		754	245(161-290)[3]	7
15		1312	240	8
16		117	300[4]	4
17	Cattle (*Bos cavus*)		(35-40)	1
18			(45-50)	1
19			106(100-115)[4]	1
20	Cattle (*B. taurus*)		45	9,10
21		500,000	43	11
22	Cattle, dairy, ♀		(60-70)	5
23			71.6	12-14
24	Chipmunk, least (*Eutamias minimas*)		684(660-702)	e
25	Dog (*Canis familiaris*)		(70-120)	1,5
26			(100-200)	1
27			(50-56)[5]	5
28			(80-130)	5
29		20,000	85	4,8
30		15,000	(72-82)	4,6
31		9600	96	4,8
32		6500	120	15
33		5000	(105-125)	4,6
34		1750	180[4]	4
35		1040	208(145-275)[3,4]	7
36	Dog, dachshund (*C. familiaris*)		115(96-129)	16
37	Dog, spitz (*C. familiaris*)		106	16
38	Dog, St. Bernard (*C. familiaris*)		(74-80)	16
39	Dolphin (*Delphinus delphis*)		150	1
40	Dormouse (*Muscardinus avellanarius*)	17	(590-670)	4,17
41		23	(580-780)	4,17
42		14	610	4,18
43		14	104[1]	18
44	Elephant (*Elephas indicus*)	2,000,000	41	19
45		2,000,000	(25-28)	1
46		3,000,000	(46-50)	4,20
57		<4,090,000	30(22-39)	21
48	*Ferret, European (Putorius sp)*		231(216-242)	e
49	Giraffe (*Camelopardalis giraffa*)		66	1
50	Goat (*Capra hircus*)		(60-80)	1
51			(70-90)	4,5
52			(80-100)	6
53		33,000	135	4,21
54	Guinea pig (*Cavia porcellus*)		280	5
55			300	4,15
56		300	290	4,22,23
57		400	267	4,24,25
58		593	260[3]	26
59		584	200(132-288)[3]	1,27
60		437	269(225-312)[3]	7

/1/ Hibernating /2/ Diving /3/ Anesthetized /4/ Young animal. /5/ Basal rate.

Part I. MAMMALS (Continued)

	Species	Weight g	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)
61	Hamster (Mesocricetus auratus)	103	347(276-420)[3]	7
62		90	400[3]	26
63	Hedgehog (Erinaceus sp)	485	263(200-325)[3]	7
64	Hedgehog (E. europaeus)	520	300(280-320)	1,2
65		520	(48-70)[6]	2
66		911	189	8
67	Horse (Equus caballus)		37(32-44)	1,5
68			(23-46)	16
69			(25-40)	28
70			63(60-71)[4]	1
71		450,000	(36-40)	4,29
72		400,000	(34-46)	1
73		380,000	55	8
74	Horse, thoroughbred (E. caballus)		(38-45)	5
75	Hyena (Hyaena hyaena)		55	1
76	Lemming, collared (Dicrostonyx rubicatus)		416(348-465)	e
77	Lion (Felis leo)		40	1
78	Manatee (Trichechus sp)	170,000-330,000	50	30
79		170,000-330,000	30[2]	30
80	Marmot (Marmota marmota)		80	1
81		3600	186(160-206)	4,31
82	Monkey (Macaca irus)		215	32
83	Monkey (M. mulatta)		165	a
84			215	f
85	Mouse (Mus musculus)		300	1
86			600	4,5
87			655	4
88		29	376[3]	26
89		17.4	500(450-550)[3]	7
90		12	670[4]	4,33
91	Mouse, white-footed (Peromyscus sp)	22	420[3]	26
92	Mouse, wild	22	480[3]	26
93	[illegible]		(46-50)	1
			120	1,34
			60	1
		140,000-180,000	110	3
		140,000-180,000	50[2]	3
98	Rabbit (Lepus sp)	1344	251(167-330)[3]	7
99	Rabbit (L. cuniculus)		(120-160)	1
100			235	1
101			187	14
102			240	4
103		1434	220	4,8
104		2000	205	4,35
105	Rabbit (L. europaeus)	2500	64(60-70)	4,36
106	Rat (Mus ratta)		400	1,5
107			420	4
108			(300-320)	4,14
109			(300-500)	28
110			(350-550)	37
111		200	(360-520)	4,17
112	Rat (Rattus norvegicus)		362	38
113			520[4]	f
114		252	352(260-450)[3]	7
115	Rat, white	6.3-8.0	301(279-317)[7]	39
116		10	309(292-331)[7]	39
117		18-20	488(407-624)[7]	39
118		92-210	305(270-350)[5]	39
119		92-210	538[7]	39
120		92-210	656[8]	39
121		237	347[3]	26
122	Seal (Phoca vitulina)	20,000-25,000	100	40
123		20,000-25,000	10[2]	40

/2/ Diving. /3/ Anesthetized /4/ Young animal. /5/ Basal rate. /6/ Cold. /7/ Held. /8/ Fettered

43. HEART RATE VERTEBRATES (Continued)

Part I: MAMMALS (Continued)

	Species	Weight g	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)
124	Sheep (Ovis aries)		180	14
125			(60-80)	1,5
126		50,000	(70-80)	29
			[illegible]	[illegible]
134			(3[illegible]0-400)[illegible]	42
135			37[1]	42
136	Swine (Sus domesticus)	100,000	(60-80)	1,5
137		130,000	(70-86)	4,6
138	Tapir (Tapirus indicus)		44	3
139	Tiger (Felis tigris)		64	3
140	Vole, field (Microtus arvalis)	21.3	522[3]	7
141	Wallaby (Macropus sp)		125	14
142	Weasel, long-tailed (Mustela frenata)		182(172-192)	e
143	Weasel, short-tailed (M. erminea)		357(300-420)	e
144	Whale, beluga (Delphinapterus sp)		(15-16)	43

/1/ Hibernating. /3/ Anesthetized /9/ Awakened from sleep. /10/ Excited, struggling

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Part II: BIRDS

	Species	Weight g	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)
1	Blackbird (Turdus merula)	58	(390-560)	1,2
2	Bramblefinch (Fringilla montifringilla)	22	(900-920)	1,2
3	Buzzard (Buteo buteo)	658	301(206-351)	3,4
4	Buzzard (B. vulgaris)		282	1,5
5			300	1
6	Canary (Serinus canarius)		690(570-840)	6
7		16	514[1]	7
8		16	1000[2]	7
9	Cardinal (Richmondena cardinalis)	40	375[1]	7
10		40	800[2]	7
11	Cassowary (Casuarius galeatus)	60,000	70	1
12	Catbird (Dumetella sp)		330(318-354)	8
13	Chaffinch (Fringilla coelebs)	15	700	1,2
14	Chickadee, black-capped (Penthestes atricapillus)	12	480[1]	7
15		12	1000[2]	7
16	Chicken (Gallus bankiva)	1000	354	5
17		1980	312(178-458)	3,4
18		1920-3120	346(304-390)	3,9
19	Chicken (Pullus gallinaceus)		(150-180)	10-12
20			(200-400)	10,13
21	Crane, Stanley (Arthropoides paradisea)	11,000	120	1
22	Crow, hooded (Corvus cornix)	360	378(312-492)	3,4
23	Dove, mourning (Zenaidura macroura)	130	135[1]	7
24		130	570[2]	7
25	Duck, domestic (Anatis pullus)	2060	240	1,14
26		2304	212(133-268)	1,4
27	Duck, wild (Anas boscas)		(120-200)	15
28			40[3]	15
29		770-1000	190(185-195)	16
30		785	317(229-420)	3,4
31	Falcon (Falco peregrinus)		347	1,4
32	Falcon (F. tinnunculus)	159	367	1,4
33	Goldfinch (Carduelis elegans)	16	920(914-925)	1,14
34	Goose (Anser sp)	2800	144	1,5
35		4000	80	1,17
36	Goshawk (Astur palumbarius)	960	347	3,4
37	Greenfinch (Chloris chloris)		710	1,2
38		25-27	773(703-848)	1,9,14
39	Gull (Larus canus)	388	401(360-483)	3,4
40	Hummingbird (Archilochus colubris)	4	615[1]	7
41	Jackdaw (Corvus monedula)	140	342(326-358)	3,4
42	Kingfisher (Alcedo ispida)	42	440	3,9,14
43	Kite (Milvus milvus)	950	258	3,4
44	Ostrich (Strutheo camelus)	80,000	65(60-70)	1
45	Parrot (Psittacus erithacus)	430	320	1,3,14
46	Pigeon (Columba sp)		(150-300)	3
47			130(120-141)	1,9
48			300(220-360)	3
49			200	9
50		237	244	3,4
51		240-370	185(141-225)	3,9,14
	[illegible]	20	890	1,2
			570(520-620)	6
		341	380(352-440)	1,3,4,16

/1/ Basal rate. /2/ Maximum rate on nest. /3/ Apneic.

Part II. BIRDS (Concluded)

	Species	Weight g	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)
55	Sparrow, chipping (Spizella passerina)	12	440[1]	7
56		12	1060[2]	7
57	Sparrow, English (Passer domesticus)		460	3
58		20	(640-910)	1,2
59		21-27	804(745-850)	3,9,14
60		28	350[1]	7
61		28	902[2]	7
62	Sparrow, song (Melospiza melodia)	20	450[1]	7
63		20	1020[2]	7
64	Starling (Sturnus vulgaris)		388(375-400)	6
65	Swan (Cygnus olor)		257	18
66	Thrasher, brown (Toxostoma sp)		278(270-294)	8
67	Titmouse, great (Parus major)	14	870	1,2
68	Towhee (Pipilo erythrophthalmus)	40	445[1]	7
69		40	810[2]	7
70	Turkey, domestic (Meleagris gallopavo)	8750	93	3,4
71	Vulture (Gyps fulvus)	8310	199	3,4
72	Warbler, yellow (Dendroica aestiva)		480[1]	8
73			832[2]	8
74	Wren, house (Troglodytes aedon)	11	450[1]	7
75		11	950[2]	7

/1/ Basal rate. /2/ Maximum rate on nest.

Contributors: (a) Robb, Jane Sands, (b) Garb, Solomon, (c) Kruta, Vladislav, and Václav Seliger, (d) Woodbury, Robert A., (e) Walker, Sheppard M., (f) Nardone, Roland M.

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Part III: REPTILES AND AMPHIBIANS

	Species	Specification	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)
1	Blindworm (Anguis fragilis)		64	1
2	Crocodile (Crocodilus sp)		(10-60)	2,3
3		72 g	(22-47)	2
4		15°C	30	4
5		23.5°C	70	1
6	Lizard (Lacerta viridis)	15-19 g	(60-66)	2
7	Lizard, sand (L. agilis)		50	5
8	Ringsnake (Coluber natrix)		68	1
9			60	1,6
10		169 g	(23-41)	1,2
11	Tortoise (Emys lutaria)		(9-60)	1
12			(16-36)	5

Part III: REPTILES AND AMPHIBIANS (Concluded)

	Species	Specification	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)
13	*Tortoise (Pseudomys rugosa)*		(21-44)	1
14	Tortoise (Testudo denticulata)	5000 g; 28-30°C	17(11-37)	7
15	Tortoise (T. graeca)	135 g	(10-20)	1,3
16	Tortoise (Thalassochelys sp)		11	1
17	Viper (Vipera berus)		40	1
18	Frog (Rana pipiens)		(40-50)	1
19			(37.5-60)	1
20	Frog (R. pipiens, R. temporaria)	2°C	(5-9)	8
21		22°C	(34-39)	8
22	Salamander (Salamandra sp)		(30-40)	9
23	Toad (Bufo sp)		(40-50)	1
24			48	10

Contributors: (a) Robb, Jane Sands, (b) Kruta, Vladislav, and Václav Seliger, (c) Garb, Solomon, (d) Walker, Sheppard M., (e) Nardone, Roland M., (f) Woodbury, Robert A.

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Part IV. FISHES

	Species	Heart Rate beats/min	Reference
	(A)	(B)	(C)
1	Barbel (Barbus fluviatilis)	(35-58)	1
2		(36-90)[1]	2
3	Bass, largemouthed (Microcropterus salmoides)	20(5-50)	3
4	Blenny (Zoarces viviparus)	(71-86)	1
5	Bullhead (Ameirus sp)	22(5-50)	3
6	Carp (Cyprinus carpio)	(40-60)	1
7		75(72-78)	4
8	Chub (Leuciscus dobula)	18[2]	5,6
9	Cod (Gadus morrhua)	(24-40)[3]	7
10		(48-60)	1
11	Dogfish, spiny (Acanthias vulgaris)	(40-50)	1
12	Dogfish, spotted (Scyllium canicula)	65[4]	5,8
13		(39-48)	1
14	Dogfish, spotted (S. catulus)	(16-50)	5
15		44[5]	9
16	Dragonet (Callionymus lyra)	(60-84)	1
17	Eel, common (Anguilla sp)	(39-68)	5
18		(20-30)	5
19		(1-2)[6]	5
20	Eel, common (A. anguilla)	(48-56)	1
21		(46-68)[7]	2
22	Eel, marine (Conger conger)	(33-50)	1
23	Goldfish (Carassius sp)	(36-40)	5
24	Gurnard (Trigla hirundo)	(62-86)	1
25	Herring (Telestes multicellus)	(36-60)	5
26	Perch (Perca fluviatilis)	(52-66)	1
27	Pike (Esox lucius)	(38-54)	1
28		(30-42)	5
29	Plaice (Pleuronectes platessa)	(54-76)	1

/1/ 120 g, 20°C. /2/ 24 cm. /3/ 30 cm, 18°C. /4/ 26°C. /5/ 1000 g; 16°C. /6/ Hibernating. /7/ 36 cm

Part IV. FISHES (Concluded)

	Species (A)	Heart Rate beats/min (B)	Reference (C)
30	Pogge (Agonus cataphractus)	(81-90)	1
31	Ray, electric (Torpedo sp)	(16-50)	5
32	Ray, thornback (Raja clavata)	(38-40)	1
33	Roach (Rutilus rutilus)	(50-71)	1
34	Rockling (Motella mustela)	(64-82)	1
35	Scorpion fish (Scorpaena scrofa)	(11-24)	1
36	Sculpin (Cottus scorpius)	(55-74)	1
37	Shark, gray (Carcharias sp)	30[8]	9,10
38		18[9]	9,10
39	Skate (Raja sp)	(16-50)	5
40	Skate (R. batis)	(21-33)	1
41	Stickleback (Gasterosteus aculeatus)	(60-100)	9,11
42	Tench (Tinca tinca)	(31-42)	1
43	Tope (Galeus canis)	(34-40)	1
44	Trout (Salmo trutta)	(30-46)	1
45	Wrasse (Labrus mixtus)	(40-81)	1

/8/ 100 cm /9/ 200 cm.

Contributors: (a) Kruta, Vladislav, and Václav Seliger, (b) Woodbury, Robert A., (c) Robb, Jane Sands, (d) Walker, Sheppard M., (e) Nardone, Roland M.

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44. HEART RATE: INVERTEBRATES

Heart rate varies with species, sex, age, size, environment, and temperature. Values in parentheses are ranges, estimate "c" (cf. Introduction)

Part I. TUNICATES, MOLLUSKS, CRUSTACEANS, ANNELIDS

	Species (A)	Specification (B)	Temp. °C (C)	Heart Rate beats/min (D)	Reference (E)
		Tunicates			
1	Appendicularia sp				
2	Ascidia depressa	0.25 cm			
3	Ciona intestinalis	8 cm		250	1
4	Clavellina lepadiformis			(31.3-33.0)	2
5	Cyclosalpa pinnata			(17-32)	3
6	Molgula manhattanensis	8 cm		(30-50)	4
7	Perophora annectens			(26-30)	5
8	Phallusia mammillata		21-22	(30-50)	5
9	Salpa africana	20 cm		43.1	6
10	S. africana maxima			(8-9)	7
11	S. bicaudata			(26-37)	5
12	S. democratica	6 cm	15-18	(21-34)	3
13	S. fusiformis	1 cm	19	(13-32)	8
14	S. pinnata	4 cm		107	5
				(41-69)	8
		Mollusks			
15	Acroloxus lacustrio (fresh-water snail)		22	108	3
16		0.0004 g			
17	Anodonta cygnea (fresh-water mussel)	0.0015 g	20	68.6	9
18			20	57.1	9
				(12-15)	10
				(26-29)	11

Part I: TUNICATES, MOLLUSKS, CRUSTACEANS, ANNELIDS (Continued)

	Species	Specification	Temp. °C	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)
		Mollusks (continued)			
19	Anodonta cygnea (fresh-water mussel)			(4-6)	12
20	(concluded)			(1.6-3.5)	13
21				(3-6)	14
22		1.96 g	20	28.1	9
23		12.1 g	20	19.7	9
24		25.5 g	20	17.4	9
25		42 g	20	14.6	9
26		64 g	20	13.0	9
27		87 g	20	12.7	9
28	A. fluviatilis			4(2-6)	12
29	A. mutabilis	Empty		(6-7)	15
30	Anomia simplex			52	16
31	Aplysia sp	Empty		(12-20)	4
32		Exposed		(8-15)	4
33		Perfused		(15-35)	4
34	A. depilans		23-24	(33-34)	17
35		Exposed		(7-8)	17
36	A. limacina			(20-35)	18
37		347 g	20	32.3	9
38		870 g	20	28.0	9
39	Ariolimax sp			(35-40)	4
40	Arion sp			(20-36)	19
41	A. empiricorum (land snail)	16.6 g	20	48.8	9
42	Bulla sp			(10-18)	4
43	Cardium echinatum	Empty		(6-7)	15
44	Carinaria meditor			54	4
45	Cepaea memorosa	0.24 g	20	65.4	9
46		0.92 g	20	63.0	9
47		2.05 g	20	52.9	9
48	Cryptochiton sp			(5-7)	4
49	Cyclas cornea			(40-50)	20
50	Dreissensia polymorpha	0.1-0.2 cm		(54-60)	21
51		2 cm		(30-35)	21
52		0.000065 g	20	60	9
53		0.67 g	20	35	9
54	Eledone sp			(35-38)	22
55				(25-30)	23
56		Perfused in situ		(20-25)	24
57	Fulgar carica			(0.8-1.0)	25
58	Haliotis tuberculata			(40-50)	26-28
59	Helix hortensis			40	23
60	H. pomatia (land snail)			(40-50)	4
61				(30-35)	5
62				(20-40)	10
63				(53-55)	4, 5
64		In situ, empty		(10-15)	4
65		Suspended, empty		(35-40)	4
66		Suspended, filled		(50-60)	4
67		0.123 g	20	60.3	9
68		0.37 g	20	68.0	9
69		0.63 g	20	47.6	9
70		8.2 g	20	42.4	9
71		14.3 g	20	37.9	9
72		24.8 g	20	35.2	9
73		36.7 g	20	37.1	9
74		At same arterial and venous pressure	20	25.3	29
75		At peak efficiency	20	22 4	29
76	Ischnochiton sp			(15-25)	4, 30
77	Limax agrestis (land snail)	0.213 g	20	90.6	9
78	Limnaea auricularia (fresh-water snail)	0.1-0.2 cm		100	21, 31
79		2 cm		(42 5-46.0)	21, 31
80		0.0008 g	20	112	9
81		0.66 g	20	46	9

Part I: TUNICATES, MOLLUSKS, CRUSTACEANS, ANNELIDS (Continued)

	Species	Specification	Temp. °C	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)
		Mollusks (continued)			
82	Limnaea stagnalis (fresh-water snail)	0.00078 g	20	55.4	9
83		3.16 g	20	21.0	9
84	Loligo sp			60	4
85				(70-80)	4
86	Lucapina sp			(12-20)	4
87	Melanoides tuberculata	0.00345 g	20	53.6	9
88		0 46 g	20	39.4	9
89	Montereina sp			(20-30)	4
90	Murex trunculus	Excised, not stretched		7(2-61)	32
91	Musculium sp	0.0366 g	20	32.9	9
92		0.141 g	20	35.5	9
93		0.171 g	20	27.5	9
94	Mya arenaria			14	4
95		Empty		(5-10)	10
96	Mytilus edulis			(15-25)	27
97		Empty		10	4
98		0 104 g	20	49.2	9
99	Natica sp			(5-7)	4
100	Octopus vulgaris			(35-40)	33
101		Suspended, empty		(8-18)	4
102		Filled		(12-20)	4
103		Perfusion pressure, 45 cm H_2O		(49-53)	33
104		Perfusion pressure, 85 cm H_2O		(53-59)	33
105	Ostraea edulis			(25-30)	27
106	Pecten jacobaeus			50	34
107				22	35
108	Phyllirhoe sp			36	36
109	Physa acuta	0 00041 g	20	65.2	9
110		0 0052 g	20	65.7	9
111		0 0129 g	20	58.2	9
112		0 055 g	20	54.8	9
113		0.153 g	20	34.4	9
114	Pisidium sp			(60-75)	21
115		0.00016 g	20	74	9
116		0.00234 g	20	58	9
117	Planorbis corneus (fresh-water snail)			(40-45)	23
118		0 0012 g	20	56.7	9
119		0.0136 g	20	43.3	9
120		0 018 g	20	45.0	9
121		0.054 g	20	39.0	9
122		0.1 g	20	35.9	9
123		0.459 g	20	32.1	9
124		0.53 g	20	26.0	9
125		1 1 g	20	25.2	9
126		1 77 g	20	29.6	9
127		1 85 g	20	21.3	9
128		3 15 g	20	20.3	9
129		4.07 g	20	13.6	9
130		5.5 g	20	15.9	9
131	P marginatus (fresh-water snail)	0.184 g	20	25.7	9
132	Pleurobranchea sp			(20-30)	4
133	Pterotrachea sp			67(50-80)	3
134				50	37
135			13-14	48(36-57)	38
136	Sepia officinalis			40	39
137		Perfused median ventricle, in situ		(18-30)	40, 41
138	Succinea sp			26	5
139	S putris	0.08 g	20	74 2	9
140		0.159 g	20	71.7	9
141		0.496 g	20	69.1	9
142	Sycotypus sp			(12-20)	30
143	Theodoxus fluviatilis	0.00341 g	20	80.2	9
144		0 0105 g	20	65.6	9
145		0 0345 g	20	63.8	9
146		0.97 g	20	49.8	9

Part I: TUNICATES, MOLLUSKS, CRUSTACEANS, ANNELIDS (Continued)

	Species	Specification	Temp. °C	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)
	Mollusks (concluded)				
147	Triopa sp			(30-40)	4
148	Unio pictorum	5.3 g	20	25.7	9
149	Valvata piscinalis			100	21, 31
	Crustaceans				
150	Alphaeus dentipes	0.16 g	20	181	42
151	Apherusa bispinosa	0.02 g	20	335	42
152	Asellus aquaticus	0.0008 g	20	310	42
153		0.0061 g	20	242	42
154		0.035 g	20	(177-182)	43
155	Astacus fluviatilis (fresh-water crab)			(30-60)	5, 44, 45
156		Empty		(10-20)	46
157		Filled		60	46
158	A. marinus (crayfish)			50(30-87)	47
159	Callianassa subterranea	1.8 g	20	136	42
160	Callinectes sapidus		22-23	(25-84)	25
161	Cancer pagurus (hermit crab)			(90-120)	4
162		Empty		(15-30)	4
163		Perfused		(15-50)	4
164		200 g	20	105	42
165	Caprella sp	0.04 g	20	140	42
166	Daphnia sp (water flea)			140	48
167				(200-250)	49
168				(200-380)	50
169			20-22	228(188-289)	3
170	D. magna		20	240	51
171	D pulex	0.000025 g	20	486	42
172		0.00024 g	20	470	42
173		0.0013 g	20	444	42
174		0.0011 g	20	490.6	43
175		0.0008 g	20	(381-418)	42
176	Dromia vulgaris	150 g	20	87	42
177		250 g	20	64	42
178	Eriphia spinifrons	75 g	20	90	42
179	Gammarus pulex	0 0011 g	20	339	42
180		0.035 g	20	258	42
181	Hippolyte sp	0.028 g	20	216	42
182	Homarus vulgaris	450 g	20	50	42
183	Hyale camptonyx	0.02 g	20	285	42
184	Leander serratus	0.77 g	20	146	42
185	Limnadia sp			(130-170)	52
186	Limulus polyphemus (king crab)			20(18-28)	4
187				15	25
188	Lysmata seticaudata	0.56 g	20	156	42
189	Maia sp			25	53
190				46	54
191	M. verrucosa	79 g	20	100	42
192	Mysis sp		19-20	260(140-320)	3
193	M. lamorn	0.02 g	20	285	42
194	Palinurus sp	Empty		35(30-50)	4
195	P. vulgaris	220 g	20	107	42
196	Pontonia custos	0 81 g	20	167	42
197	Porcellana sp	Larva	20	170	3
198	Potamobius astacus	30 g	20	100	42
199	Sparassus virescens	Moderate activity		120	55
200		Intense activity		(200-230)	55
201	Squilla eusebia	Larva	26	240	3
202	S. mantis	27 g	20	90	42
	Annelids				
	[illegible]			7(6-8)	56
	[illegible]			6	57
	[illegible]			17(15-20)	35
	[illegible]			8	35
	[illegible]		7	4.6	58
207			35	50	58
208					

Part I. TUNICATES, MOLLUSKS, CRUSTACEANS, ANNELIDS (Concluded)

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Part II INSECTS

	Insect (A)	Specification (B)	Temp. °C (C)	Heart Rate beats/min (D)	Reference (E)
	Thysanura				
1	Campodea sp				
2	Machilis sp		16-18	(79-81)	1
			20	(150-160)	2
	Ephemeroptera				
3	Cloëon dipterum	Nymph			
4	C rhodani	Nymph	15-16	(31-34)	3
			15-16	(77-112)	3
	Odonata				
5	Anax junius				
			28	60(28-100)	4
	Orthoptera				
6	Blatta orientalis	Nymph to adult			
7		Nymph to adult		(75-105)[1]	5
8				67.2(50-107)[1]	6
9		Nymph	18	(60-80)	6
10	Blattella germanica	Nymph		(35-65)[1]	7
11	Dermacentor andersoni		25-27	120	8
12	Grasshopper	Nymph to adult		(20-28)	9
13	Locusta migratoria danica	Male	25	60[1]	10
14		Male	26	(25-75)[1]	11
15		Female	29	(80-120)[1]	11
16	Melanoplus differentialis	Nymph to adult	29	(80-130)[1]	11
17		Nymph to adult	25	65[1]	12
18	Periplaneta americana	Nymph, male	21-26	(40-70)	13
19		Nymph, female		94	14
20		Nymph to adult		100	14
				(80-110)[1]	15

/1/ Heart exposed by dissection and examined under physiological saline

Part II: INSECTS (Continued)

	Insect	Specification	Temp. °C	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)
	Orthoptera (concluded)				
21	Periplaneta americana	Nymph to adult		(90-130)[1]	16
22	(concluded)	Nymph to adult	20-26	117.3(99-147)	17
23		Nymph to adult	26-27	(90-100)[1]	18
24		Nymph to adult	29	49(18-70)[1]	19
25		Adult	18	72.9(22-150)[1]	20
26		Adult, male		99	14
27		Adult, female		99	14
28	Stenopelmatus longispina	Nymph	25	41(30-52)[1]	21
	Mallophaga				
29	Menopon pallidum			(112-120)	22
	Anoplura				
30	Pediculus sp			(30-48)	23
	Hemiptera				
31	Belostoma sp			(34-35)	24
32	Nezara viridula		27	100	25
33	Notonecta sp			70	24
34	Rhodnius prolixus	Nymph	25-27	30	8
	Homoptera				
35	Aphis sp		18	(68-80)	6
36	Macrosiphum tulipae		23	83	26
	Neuroptera				
37	Chrysopa sp		18	(50-60)	6
	Trichoptera				
38	Phryganid	Larva	25	26	26
	Lepidoptera				
39	Bombyx mori			58	27
40		Larva		(20-67)	28
41		Larva		(66-76.8)	29
42		Larva	25	54	30
43		Larva, stage 2		70	31
44		Larva, stage 3		65.7	31
45		Larva, stage 4		54 8	31
46		Larva, stage 5		45.7	31
47		Larva, stage 5	27	55.9	32
48		Larva, calm		(44-66)	31
49		Larva, excited		94	31
50		Larva, spinning		55	31
51		Adult, resting		(40-50)	33
52		Adult, active		(110-140)	33
53	Celerio euphorbiae			39	34
54	Cerura virula		21-27	(49-88)	33
55	Colias eurytheme	Larva		(60-120)	6
56	C. hyale			(54-66)	35
57	Dendrolimus pini	Pupa		(50-60)	6
58	Ephestia kuhniella	Pupa		(6-11)	36
59	Galleria mellonella		25.0-29.5	(60-69)	37
60		Larva, spinning	25	(50-80)	37
61	Parage maera		20-30	(40-80)	6
62	Pieris brassicae	Larva		29	38
63		Larva, parasitized with Apanteles		6	38
64	Prodenia eridania	Larva	29	58(40-90)[1]	19
65	Saturnia pavonia major	Pupa		(0-39.8)	39
66	Sphinx ligustri	Larva	22	(38-54)	33
67		Pupa		27	34
	Coleoptera				
68	Dytiscus marginalis			60[1]	40
69		Intact		(30-70)	40
70		Isolated fragment		6	40
71		Isolated heart		15	40
72	Lucanus cervus		18	15.7	41
73		Larva	13	14.1	41
74	Oryctes nasicornis		25	18	30
75			24-33	(17-31)	6

/1/ Heart exposed by dissection and examined under physiological saline.

Part II. INSECTS (Continued)

	Insect (A)	Specification (B)	Temp. °C (C)	Heart Rate beats/min (D)	Reference (E)
		Coleoptera (concluded)			
76	Prionus laticollis		29	118	27
77	Tenebrio molitor	Larva		(15-17)	42
78		Larva, postmolt		20	42
79		Pupa		10	42
		Hymenoptera			
80	Anthophora retusa			142	6
81	Sphex sp	Adult	28	(300-354)	27
		Diptera			
82	Aedes diversus	Larva	18	50(47.6-55.6)	43
83	A. togoi	Larva	25	48(43.7-52.5)	44
84	Anopheles maculipennis	Adult	20	(79-110)	27
85		Adult, after blood meal	20	109.9	27
86		Adult, digesting	20	91.7	27
87	A. quadrimaculatus	Larva, stage 1	25-27	131.7	45
88		Larva, stage 2	25-27	134.3	45
89		Larva, stage 3	25-27	118.6	45
90		Larva, stage 4	25-27	106.6	45
91		Pupa	25-27	109.1	45
92		Adult, female	25-27	151.2	45
93		Adult, female	25-27	80.7[1,2]	45
94	Calliphora	Larva		120.8	46
95		Larva	18	60[1]	47
96	Chironomus sp	Larva	15-19	(61.5-133.2)	48
97	C. dorsalis	Larva		162	49
98	C. plumosus	Larva	17	90	49
99	Corethra albipes	Larva	27	(19-29)	50
100	C. plumicornis	Larva		(21-24)	51
101		Larva	17-18	(15-16)	52
102		Larva		16.8(12-41)[1]	53
103		Larva, calm		(12-14)	54
104		Larva, active		22	54
105	Culex sp	Larva		(50-100)	55
106	Culex pipiens	Larva, stage 2		100	56
107		Larva, stage 4		90	56
108		Larva, stage 4		60(56.5-65.5)	43
109		Larva, stage 4	25-27	(110-140)	8
110	Culicoides nubeculosus	Larva		(30-85)	57
111	Drosophila funebris		30	251	58
112		Adult	28-29	235	58
113	Hippobosca equina		23 5	120	59
114	Mocholonyx velutina	Larva	18	(20-28)	43
115		Larva	21	(27-31.5)	43
116	Oestrus			(40-44)	6
117	Pachyrhina ferruginia	Adult, male	22	128	27
118	Phormia	Larva	18	60[1]	47
119	Tipula maxima	Larva		24	60
120	T selene	Larva	18	48	61
121		Pupa	18	(40-60)	61

/1/ Heart exposed by dissection and examined under physiological saline /2/ Standard error on 100 insects, ±1.8.

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Part II. INSECTS (Continued)

	Insect	Specification	Temp. °C	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)
		Orthoptera (concluded)			
21	Periplaneta americana (concluded)	Nymph to adult		(90-130)[1]	16
22		Nymph to adult	20-26	117.3(99-147)	17
23		Nymph to adult	26-27	(90-100)[1]	18
24		Nymph to adult	29	49(18-70)[1]	19
25		Adult	18	72.9(22-150)[1]	20
26		Adult, male		99	14
27		Adult, female		99	14
28	Stenopelmatus longispina	Nymph	25	41(30-52)[1]	21
		Mallophaga			
29	Menopon pallidum			(112-120)	22
		Anoplura			
30	Pediculus sp			(30-48)	23
		Hemiptera			
31	Belostoma sp			(34-35)	24
32	Nezara viridula		27	100	25
33	Notonecta sp			70	24
34	Rhodnius prolixus	Nymph	25-27	30	8
		Homoptera			
35	Aphis sp		18	(68-80)	6
36	Macrosiphum tulipae		23	83	26
		Neuroptera			
37	Chrysopa sp		18	(50-60)	6
		Trichoptera			
38	Phryganid	Larva	25	26	26
		Lepidoptera			
39	Bombyx mori			58	27
40		Larva		(20-67)	28
41		Larva		(66-76.8)	29
42		Larva	25	54	30
43		Larva, stage 2		70	31
44		Larva, stage 3		65.7	31
45		Larva, stage 4		54 8	31
46		Larva, stage 5		45.7	31
47		Larva, stage 5	27	55.9	32
48		Larva, calm		(44-66)	31
49		Larva, excited		94	31
50		Larva, spinning		55	31
51		Adult, resting		(40-50)	33
52		Adult, active		(110-140)	33
53	Celerio euphorbiae			39	34
54	Cerura vinula		21-27	(49-88)	33
55	Colias eurytheme	Larva		(60-120)	6
56	C. hyale			(54-66)	35
57	Dendrolimus pini	Pupa		(50-60)	6
58	Ephestia kuhniella	Pupa		(6-11)	36
59	Galleria mellonella		25.0-29.5	(60-69)	37
60		Larva, spinning	25	(50-80)	37
61	Parage maera		20-30	(40-80)	6
62	Pieris brassicae	Larva		29	38
63		Larva, parasitized with Apanteles		6	38
64	Prodenia eridania	Larva	29	58(40-90)[1]	19
65	Saturnia pavonia major	Pupa		(0-39.8)	39
66	Sphinx ligustri	Larva	22	(38-54)	33
67		Pupa		27	34
		Coleoptera			
68	Dytiscus marginalis			60[1]	40
69		Intact		(30-70)	40
70		Isolated fragment		6	40
71		Isolated heart		15	40
72	Lucanus cervus	Larva	18	15.7	41
73			13	14.1	41
74	Oryctes nasicornis		25	18	30
75			24-33	(17-31)	6

[1] Heart exposed by dissection and examined under physiological saline.

46. HEART RATE, BASAL AND NON-BASAL AT VARIOUS AGES MAN

Heart rate varies with sex, age, environment, and temperature Values in parentheses are ranges, estimate "b" for columns B and C, and estimate "c" for column D (cf. Introduction).

	Age yr	Heart Rate, beats/min — Basal — Male	Heart Rate, beats/min — Basal — Female	Heart Rate, beats/min — Non-Basal	Reference
	(A)	(B)	(C)	(D)	(E)
1	<1			134(101-160)	1
2	1	116	122	113(84-136)	B, C, 2, D, 1
3	2	104	103	108(84-134)	
4	3	92	86	108(80-124)	
5	4		87	103(80-133)	
6	5		91	98(70-128)	
7	6	87	80	93(72-128)	
8	7	85	73	94(72-112)	
9	8	80	77	89(72-114)	
10	9	81	85	91(68-120)	
11	10	79	80	87(56-106)	
12	11			89(60-120)	1
13	12	69 5(53.3-85 7)	71.4(55 8-87 0)	88(67-112)	B, C, 3, D, 1
14	13	65 9(53 9-77.9)	67.8(51.8-83.8)	87(66-114)	
15	14	67.1(53.1-81.1)	68.3(54 5-82.1)	82(60-112)	
16	15	65.2(54 2-76 2)	67.3(50.1-84 5)	83(66-112)	
17	16	61 6(48 6-74 6)	65.8(50.6-81 0)	80(54-108)	
18	17	58.6(49 0-68.2)	64.1(50 3-77.9)	76(54-104)	
19	18		73	77(60-108)	C, 2, D, 1
20	19	65	71	74(52-106)	B, C, 2, D, 1
21	20	64	69	71(59-99)	
22	20-40	62	68		
23	21				2
24	22			71(41-96)	1
25	23			70(56-100)	
26	24	61 0(47-75)	69 2(52.4-86.0)	71(50-96)	
27	25-30			72(50-96)	B, C, 3, D, 1
28	25-44			72(52-102)	1
29	30	59.3(47 1-71.5)	64 8(47.8-81.8)	71(50-104)	4
30	30-35				3
31	34	71 7(64 9-78.5)		70(58-104)	1
32	35-40				5
33	40-45			72(56-100)	1
34	40-60	57	70	72(50-104)	
35	43	69 1(63.1-75.1)			2
36	45-49				5
37	50-55			72(49-100)	4
38	50-59			72(52-94)	1
39	55	69 8(64.2-75 4)		73(48-108)	4
40	55-60				5
41	60-65			75(48-108)	1
42	60-70	66		73(54-100)	
43	65	63 0(56 6-69.4)	71	74(52-100)	
44	65-70				B, C, 2, D, 4
45	70-75			73(52-96)	5
46	70-79			75(54-104)	1
47	>70	65		75(50-104)	
48	73	65.8(58 6-73.0)	73		4
49	75-80				2
50	>80			72(50-94)	5
51	82	67 0(52-82)		77(63-98)	1
					4
					5

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45. HEART RATE OF EMBRYO AND NEWBORN: MAMMALS

Heart rate varies with species, sex, age, size, environment, and temperature. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	Heart Rate beats/min	Reference
	(A)	(B)	(C)
		Embryo	
1	Man, 5th mo	156(150-160)	1
2	6th mo	154(141-155)	
3	7th mo	149(118-156)	
4	8th mo	142(129-152)	
5	9th mo	146(131-173)	
6	Dog	(120-170)	2
7	Goat	(120-246)	1
8	Monkey	(100-200)	1
9	Ox	161	2
10	Rat	(95-256)	1
		Newborn	
11	Man, premature	145(110-185)	3
12	Man, full-term	(130-140)	
13	Cat	300	2, 4
14	Dog	(160-180)	2
15	Goat	(145-240)	1
16	Horse	(100-120)	5
17	Ox	(141-160)	2
18	Pig	227	4
19	Rabbit	220	6
20	Rat	161(121-201)	4

Contributors: (a) Johnson, Richard P., (b) Woodbury, Robert A.

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Part III INTACT ANIMALS

	Animal	Experimental Condition	Site of Temperature Recording	Heart Rate At Temp., °C	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Man	Anesthetized or unanesthetized in water at 2-12°C[1]	Rectum	30	Atrial fibrillation	1
2				34	50	
3				37	80-90	
4		Sedated with barbiturate, and cooled with brine-circulated blanket	Deep rectum	29	60	2
5				32	83	
6				35	95	
7				37	100	
8	Cat	Deeply anesthetized with chloralose	Deep rectum	30	100	3
9				32	150	
10				34	175	
11				36	190	
12				38	225	
13				40	210	
14	Dog	Anesthetized with sodium pentothal, artificial respiration when necessary	Right heart blood	17	17	4,5
15				19	24	
16				21	32	
17				23	44	
18				25	63	
19				27	84	
20				29	108	
21				31	132	
22				33	147	
23				35	161	
24				37	174	
25		Anesthetized with sodium pentobarbital, O_2 plus inhalation anesthetics with respirator	Rectum	22	38	6
26				24	51	
27				26	70	
28				28	89	
29				30	108	
30				32	123	
31				34	147	
32				36	175	
33	Guinea pig	Deep urethane narcosis	Deep rectum	30	212	3
34				32	216	
35				34	227	
36				36	240	
37				38	256	
38				40	287	
39				42	283	
40		Unanesthetized and restrained[2]	Colon	23	75	7
41				25	120	
42				30	210	
43				35	295	
44				38	350	
45	Hamster, golden	Unanesthetized, during arousal from hibernation	Cheek pouch	5	14	8
46				10	50	
47				15	105	
48				20	185	
49				25	270	
50				30	380	
51				35	500	
52	Monkey[3]	Anesthetized with sodium pentobarbital, artificial respiration with 100% O_2	Rectum	23	50	9
53				30	100	
54				33	140	
55				37	167	
56	Rabbit, albino	Unanesthetized[4]	Deep rectum	20	20-40	10
57				25	40	
58				28	70	
59				39	200	

/1/ Immediately after immersion, heart rate = 120-140 beats/min. Lethal temperature variable and uncertain. /2/ At body temperature of less than 23°C, heart rate irregular. /3/ Age, 12-18 months. /4/ After immersion, heart rate = 270 beats/min. At body temperature of less than 20°C, heart beat irregular and weak.

47. EFFECT OF TEMPERATURE ON HEART RATE: VERTEBRATES

Part I: PER DEGREE TEMPERATURE CHANGE

	Animal	Temp. range[1] °C	Condition or Method Effecting Temp. Change	Heart Rate Change per °C Temp. Change beats/min	Heart Rate Change per °F Temp. Change beats/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Man	36.0-41.0	Fever induced by short radio-waves	7.4-30.6	4.1-17.0	1
2		36.9-38.9	Lobar pneumonia	10.4-27.2	5.8-15.1	2
3		35.6-39.4	Peptone injections	17.6	9.8	2
4		36.9-38.9	Hot baths	18	10	3
5		36.1-37.3	Regression of resting heart rate	19.8	11.01	4
			heart			
15		0-30	Perfused isolated heart	1.7-5.0	0.9-2.8	14

/1/ Of body, or of isolated heart. /2/ Urethane anesthetized. /3/ Anesthetized

Contributor. Cooper, K. E.

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Part II· ISOLATED HEART

	Animal	Experimental Condition	Site of Temperature	Heart Rate, beats/min At Temp., °C.									Reference
				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	(M)
		genated Ringer's											1
2	Cat	Denervated heart-lung preparation	Blood in venous cannula						75	102	153	165	2
3	Dog	Denervated heart-lung preparation	Sino-atrial node tissue						45	88	132	160	3
4	Rabbit	Atria immersed in oxygenated Ringer's	Ambient fluid					30	65	100	147	230	4
5	Frog	Whole heart immersed in oxygenated Ringer's, during summer	Ambient fluid	9[2]	13	23	35	44	52[2]	60[2]			5
6		Whole heart immersed in oxygenated Ringer's, during winter	Ambient fluid	5	8	20	30	42	57	72			4

/1/ 13 weeks. /2/ Only in South African frog

Contributor: Badeer, Henry

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48. EFFECT OF EXERCISE ON HEART RATE: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Exercise	Age yr	No of Subjects	Sex	Body Weight kg	Body Height cm	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	6 min on treadmill or *bicycle* ergometer	4-6	10	♂	20.8(16 0-27.8)	113 5(107-128)	203(188-214)	1
2			7	♀	18 4(17.4-21.9)	111 6(108-114)	204(176-214)	
3		7-9	12	♂	30.7(25.1-36 5)	135 0(125-143)	208(191-220)	
4			14	♀	27.2(20 6-33 0)	132 0(121-142)	212(194-233)	
5		10-11	13	♂	36.5(31.1-44.7)	145.4(132-157)	211(200-227)	
6			13	o	32 5(27.0-37 4)	140 6(129-148)	209(192-220)	
7		12-13	19			[illegible]	205(175-237)	
8			13				[illegible]	
9		14-15	10					
10			11					
11		16-18	9					
12		16-17	10					
13		20-23	42					
14		20-25	44					2
15	5 min on treadmill	20-29	11					
16		31-38	11					
17		40-48	10					
18		48-55	8					
19		59-66	7					1
	Bicycle ergometer[1]							
20	600 kg-m/min		31	♀			138(120-1[illegible])	
21	900 kg-m/min		21	♂			128(102-148)	
22			31	♀			168(146-192)	
23	1200 kg-m/min		21	♂			148(130-169)	
24	1500 kg-m/min		21	♂			167(148-188)	
25	*Running until nearly* exhausted, then up and down flight of stairs[2]	9	1	♂	32	134 6	189[3]	3
26		10	2	[illegible]	[illegible]	(132 1-147.3)	(180-183)[3]	
27		11	4				[illegible][3]	
28		12	1					
29		13	15					
30		14	3					
31		15	1					

/1/ Well-trained subjects /2/ Duration of exercise, 2-4 minutes. /3/ One-minute count.

Contributors (a) Åstrand, Per-Olof, (b) *Asmussen, Erling,* (c) Johnson, Richard P

References [1] Åstrand, P.-O 1952. Experimental studies of physical working capacity in relation to sex and age. Ejnar Munksgaard, Copenhagen. [2] Robinson, S. 1938 Arbeitsphysiologie 10:251. [3] Boas, E. P., and E F Goldschmidt 1932 The heart rate. C. C Thomas, Springfield, Ill. p 90.

49. EFFECT OF POSTURE AND SLEEP ON HEART RATE: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction)

	Specification	No of Subjects	Sex	Age yr	Heart Rate beats/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Basal	182	♂	College	65(45-105)	1
2	Recumbent	252	♂	College	66(40-100)	
3	*Sitting*	252	♂	College	73(48-105)	
4	Standing	194	♂	College	82(54-124)	
5	Sleeping	51	♂	28 1[1]	59.4(52 8-67.1)	2
6		52	♀	24 6[1]	65 3(57 7-75 4)	
7	Awake	51	♂	28 1[1]	77.8(61.2-111.8)	
8		52	♀	24 6[1]	83 9(67.1-120 6)	

/1/ Average

Contributor Johnson, Richard P

References [1] Brouha, L , and C. W Heath. 1943 N England J. M 228 473 [2] Boas, E. P., and E. F. Goldschmidt 1932 The heart rate C C Thomas, Springfield, Ill. p 23.

Part III: INTACT ANIMALS (Concluded)

	Animal	Experimental Condition	Site of Temperature Recording	Heart Rate		Reference
				At Temp., °C	beats/min	
	(A)	(B)	(C)	(D)	(E)	(F)
60	Rabbit, albino (concluded)	Anesthetized with sodium pentobarbital	Colon	10	13	11
61				12	24	
62				14	34	
63				16	45	
64				18	59	
65				20	70	
66				22	84	
67				24	96	
68				26	115	
69				28	132	
70				30	158	
71				32	185	
72				34	211	
73				36	234	
74				38	256	
75				40	276	
76	Rat, albino	Anesthetized with sodium pentobarbital	Deep rectum	15	45	12
77				20	120	
78				25	195	
79				30	270	
80				35	345	
81		Unanesthetized and restrained	Colon	15	45	13
82				20	110	
83				25	210	
84				30	300	
85				35	405	
86				37	460	
87	Squirrel, ground	Unanesthetized, during arousal from hibernation	Food pouch	10	38	14
88				15	102	
89				20	218	
90				25	357	
91	Frog, South African	Unanesthetized and restrained	Intraventricular blood	2	4	15
92				5	11	
93				10	20	
94				15	18	
95				20	27	
96				25	34	
97				30	31	
98				36	25	
99	Fish (cod, eel, flounder, pollack, sculpin, skate)	In water	Ambient fluid	0	6	16
100				5	12	
101				12	18	
102				15	25	
103				20	32	
104				25	38	
105				30	45	

Contributor. Badeer, Henry

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41	Diastolic blood	Basal	76(59-93)	77(49-105)	80(62-98)	79(66-92)	77(66-88)	82(53-111)	75(64-86)
42	pressure,	0 5	76(61-91)	81(52-110)	82(60-104)	80(70-90)	80(59-101)	85(60-110)	74(45-119)
43	mm Hg	2 0	74(58-90)	79(49-109)	83(60-106)	82(66-98)	78(60-96)	81(54-108)	76(55-113)
44		5 0	74(57-91)	78(48-108)	81(57-105)	81(68-94)	75(61-89)	79(53-105)	72(65-95)
45		10 0	74(60-88)	77(48-106)	80(60-100)	80(67-93)	75(61-89)	78(51-105)	70(61-95)

Contributor Shock, Nathan W

Reference Shock, N W , and A. H. Norris. Unpublished.

Part II· STEP-TEST EXERCISE

Exercise walking *over* two 9-inch steps the number of times required to perform *222* kg-m of work *in* 1.5 min. Subjects seated during recovery. Blood pressure determined by auscultatory *method*. Values in parentheses *are ranges*, estimate "b" (cf. Introduction).

	Condition	Recovery Time, min	20-29 yr (17 subjects)	30-49 yr (27 subjects)	50-59 yr (19 subjects)	60-69 yr (28 subjects)	70-79 yr (28 subjects)	80-89 yr (19 subjects)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
				Heart Rate, beats/min				
1	After standing	0.25	80.1(57-103)	80.4(54-106)	81.1(54-108)	78.4(53-103)	81.1(55-107)	80 1(56-104)
2		1.25	75 0(54-96)	76.4(49-103)	78.3(52-104)	74 8(53-97)	76.3(52-100)	73.3(49-97)
3		5.00	77.1(53-101)	76 6(52-102)	77 8(51-105)	75 0(56-94)	75.6(51-101)	73 7(53-95)
4	After exercise	0 25	83 2(63-103)	87.7(67-109)	93.4(44-142)	89.3(64-114)	95 4(68-122)	92.9(64-122)
5		1 25	77 8(57-99)	77.3(47-107)	77.2(49-105)	77.2(53-101)	81 6(59-105)	79.5(54-106)
6		5 00	80 6(60-102)	78.3(50-106)	79 3(44-114)	76.5(56-98)	78 1(52-104)	73 5(51-97)
				Systolic Blood Pressure, mm Hg				
7	After standing	0.25	120.3(93-147)	126.4(81-171)	136.3(96-176)	131.1(91-171)	148 0(83-213)	145.5(101-191)
8		1.25	119.6(91-149)	126.9(77-177)	134.7(100-170)	128.6(99-159)	147.4(85-209)	142.1(98-186)
9		5 00	115 4(92-138)	122 7(83-163)	128 8(93-165)	124 8(92-158)	140.7(79-203)	136.3(93-179)
10	After exercise	0.25	129.1(107-151)	136.1(92-180)	148.0(106-190)	141.3(101-181)	162.3(88-236)	155.1(101-209)
11		1.25	122 8(98-151)	131 3(86-176)	140.6(106-176)	141.0(104-178)	162.7(87-239)	156.5(106-208)
12		5 00	118 6(93-145)	125.4(85-165)	132 3(98-166)	131.5(97-167)	149.5(84-216)	143.6(101-187)
				Diastolic Blood Pressure, mm Hg				
13	After standing	0.25	76.6(58-96)	85.9(60-112)	86.2(62-110)	80.9(52-110)	81.1(47-115)	77.8(52-104)
14		1.25	76.3(60-92)	86.4(60-112)	86 9(65-109)	80.5(56-106)	81.1(50-112)	76.7(47-107)
15		5.00	75 5(60-92)	85 0(59-111)	86 1(64-108)	78 5(55-103)	79.3(48-110)	77.0(50-104)
16	After exercise	0.25	75 3(59-91)	83.8(59-109)	84 2(58-110)	78 0(54-102)	80.4(45-115)	76.1(53-99)
17		1.25	79.5(65-95)	87 6(61-115)	89.3(66-112)	82.2(58-106)	85 0(50-120)	81.2(53-109)
18		5 00	80 8(65-97)	89.3(66-112)	89.4(65-113)	84 2(58-110)	83 9(51-117)	80.5(56-106)

Contributor: Shock, Nathan W.

Reference Norris, A. H., N. W. Shock, and M. J. Yiengst. 1953. Circulation, N. Y. 8·521.

50. RECOVERY OF HEART RATE AND BLOOD PRESSURE AFTER EXERCISE: MAN

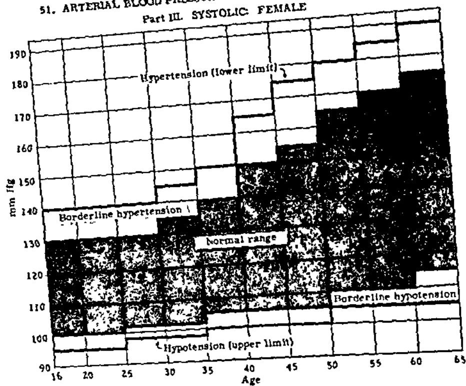
Part I: VARIOUS WORK LOADS

Exercise: cranking movement of arms. Subjects recumbent during exercise and recovery. Blood pressure determined by auscultatory method. Values in parentheses are ranges, estimate "b" (cf. Introduction).

	Variable	Recovery Time, min	20-29 yr (10 subjects)	30-39 yr (11 subjects)	40-49 yr (10 subjects)	50-59 yr (9 subjects)	60-69 yr (10 subjects)	70-79 yr (10 subjects)	80-89 yr (9 subjects)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Work Load = 500 kg-m at 135 kg-m/min								
1	Heart rate, beats/min	Basal	59(41-77)	63(45-81)	70(54-86)	69(43-95)	64(42-86)	65(40-90)	59(47-71)
2		0.5	74(58-90)	77(56-98)	82(60-104)	79(59-99)	83(57-109)	91(70-112)	92(54-130)
3		2.0	63(40-86)	67(49-85)	71(57-85)	69(48-90)	69(43-95)	71(47-95)	74(49-99)
4		5.0	62(53-71)	66(50-82)	73(52-94)	68(47-89)	66(38-94)	67(41-93)	66(45-87)
5		10.0	61(45-77)	66(49-83)	71(55-87)	68(44-92)	67(44-90)	67(42-92)	64(47-81)
6	Systolic blood pressure, mm Hg	Basal	116(95-137)	119(87-151)	118(101-135)	120(89-151)	120(87-153)	141(74-208)	163(95-231)
7		0.5	130(96-164)	133(102-192)	143(56-230)	138(110-166)	152(104-200)	178(106-250)	177(87-231)
8		2.0	123(95-151)	128(84-172)	130(101-159)	135(108-162)	142(102-182)	173(95-251)	178(101-255)
9		5.0	118(86-150)	119(84-154)	122(101-143)	125(101-149)	129(97-161)	158(76-240)	166(101-231)
10		10.0	115(90-140)	119(85-153)	119(103-135)	121(98-144)	124(101-147)	150(74-226)	156(99-213)
11	Diastolic blood pressure, mm Hg	Basal	76(64-88)	82(55-109)	80(65-95)	77(64-90)	73(60-86)	84(60-108)	78(61-95)
12		0.5	79(64-94)	83(49-117)	84(68-100)	80(72-88)	79(60-98)	88(63-113)	85(56-114)
13		2.0	76(59-93)	79(46-112)	84(63-105)	79(66-92)	77(61-93)	86(58-114)	86(65-107)
14		5.0	76(59-93)	76(47-107)	82(64-100)	78(65-91)	76(62-90)	85(57-113)	80(64-96)
15		10.0	75(59-91)	76(46-106)	83(67-99)	78(65-91)	75(64-86)	83(55-111)	79(64-94)
	Work Load = 500 kg-m at 267 kg-m/min								
16	Heart rate, beats/min	Basal	61(41-81)	63(49-77)	65(53-77)	65(41-114)	62(43-81)	63(36-90)	60(50-70)
17		0.5	81(60-102)	82(64-100)	89(62-116)	90(63-117)	95(65-125)	101(69-133)	101(62-140)
18		2.0	67(58-76)	67(48-86)	72(56-88)	72(49-95)	70(40-100)	76(52-100)	80(50-110)
19		5.0	62(53-71)	65(46-84)	66(52-80)	68(52-84)	67(38-96)	70(48-92)	67(49-85)
20		10.0	64(50-78)	65(45-85)	68(53-83)	70(46-94)	67(42-92)	70(46-94)	65(50-80)
21	Systolic blood pressure, mm Hg	Basal	115(104-126)	117(96-138)	116(94-138)	118(91-145)	127(85-169)	141(91-191)	162(102-222)
22		0.5	130(106-154)	136(104-168)	143(93-193)	147(73-221)	166(106-226)	176(116-236)	179(96-262)
23		2.0	123(102-144)	130(103-157)	138(96-180)	140(83-197)	149(105-193)	169(104-234)	187(108-266)
24		5.0	119(100-138)	122(99-145)	125(92-158)	129(105-153)	130(99-161)	149(87-211)	172(118-226)
25		10.0	116(102-130)	120(91-149)	118(96-140)	125(93-157)	126(94-158)	141(84-198)	166(111-221)
26	Diastolic blood pressure, mm Hg	Basal	74(62-86)	79(59-99)	82(63-101)	79(62-96)	77(65-89)	82(56-108)	77(64-90)
27		0.5	76(63-89)	82(60-104)	84(60-108)	82(68-96)	84(61-107)	88(62-114)	87(57-117)
28		2.0	75(65-85)	79(59-99)	83(62-104)	82(66-98)	80(58-102)	84(62-106)	88(67-109)
29		5.0	75(65-85)	77(58-96)	81(63-99)	80(64-96)	78(64-92)	83(58-108)	83(69-97)
30		10.0	75(63-87)	78(58-98)	80(63-97)	81(68-94)	78(60-96)	82(56-108)	81(66-96)
	Work Load = 350 kg-m at 450 kg-m/min								
31	Heart rate, beats/min	Basal	61(45-77)	60(49-71)	67(53-81)	65(41-89)	62(42-82)	65(37-93)	56(42-70)
32		0.5	77(61-93)	87(60-98)	89(68-110)	81(48-114)	87(61-113)	96(56-136)	92(59-125)
33		2.0	70(35-105)	73(50-84)	73(57-89)	71(48-94)	70(41-99)	75(46-104)	78(54-102)
34		5.0	62(40-84)	68(48-76)	67(52-82)	66(45-87)	66(38-94)	69(42-96)	66(50-82)
35		10.0	61(48-74)	69(47-79)	68(54-82)	66(42-90)	65(39-91)	69(41-97)	63(46-80)
36	Systolic blood pressure, mm Hg	Basal	116(92-140)	113(87-139)	114(98-130)	121(91-151)	126(88-164)	144(76-212)	157(99-215)
37		0.5	123(93-153)	127(91-163)	127(98-156)	138(119-157)	148(109-187)	167(105-229)	171(95-247)
38		2.0	118(91-145)	126(93-157)	123(99-147)	137(94-180)	141(100-182)	167(103-231)	180(96-264)
39		5.0	116(94-138)	120(88-152)	121(91-151)	130(100-160)	128(94-162)	152(80-224)	169(106-232)
40		10.0	116(99-133)	117(88-146)	115(93-137)	126(99-153)	124(96-152)	143(66-220)	158(98-218)

51. ARTERIAL BLOOD PRESSURE VS AGE AND SEX: MAN (Concluded)

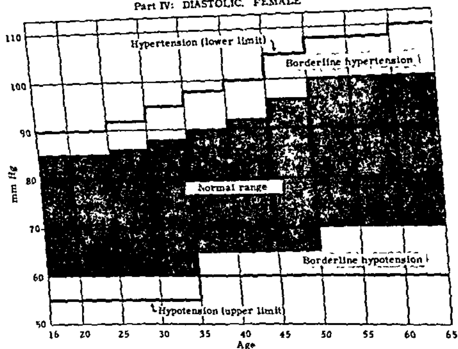
Part III. SYSTOLIC: FEMALE



Contributor: Hartroft, W. Stanley

Reference: Master, A. M., C. I. Garfield, and M. B. Walters. 1952. Normal blood pressure and hypertension. Lea and Febiger, Philadelphia. p. 100

Part IV: DIASTOLIC. FEMALE

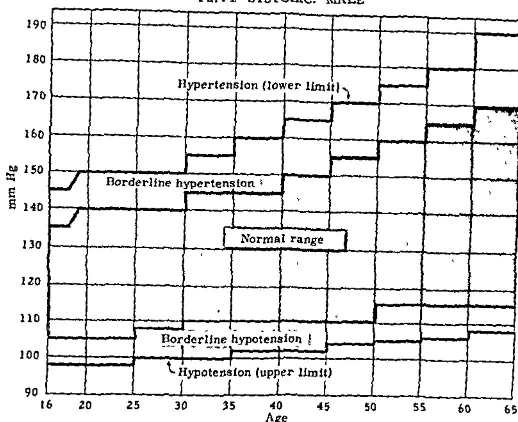


Contributor: Hartroft, W. Stanley

Reference: Master, A. M., C. I. Garfield, and M. B. Walters. 1952. Normal blood pressure and hypertension. Lea and Febiger, Philadelphia. p. 102

51. ARTERIAL BLOOD PRESSURE VS AGE AND SEX: MAN

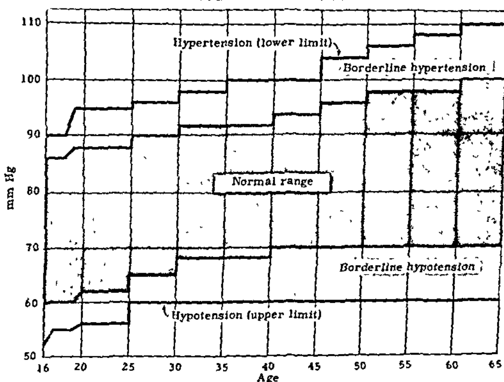
Part I. SYSTOLIC: MALE



Contributor: Hartroft, W. Stanley

Reference: Master, A. M., C. I Garfield, and M. B Walters. 1952. Normal blood pressure and hypertension. Lea and Febiger, Philadelphia, p. 99.

Part II: DIASTOLIC: MALE



Contributor: Hartroft, W Stanley

Reference: Master, A. M., C. I. Garfield, and M. B Walters 1952. Normal blood pressure and hypertension. Lea and Febiger, Philadelphia. p. 101

53. ARTERIAL BLOOD PRESSURE

Part I. MAN

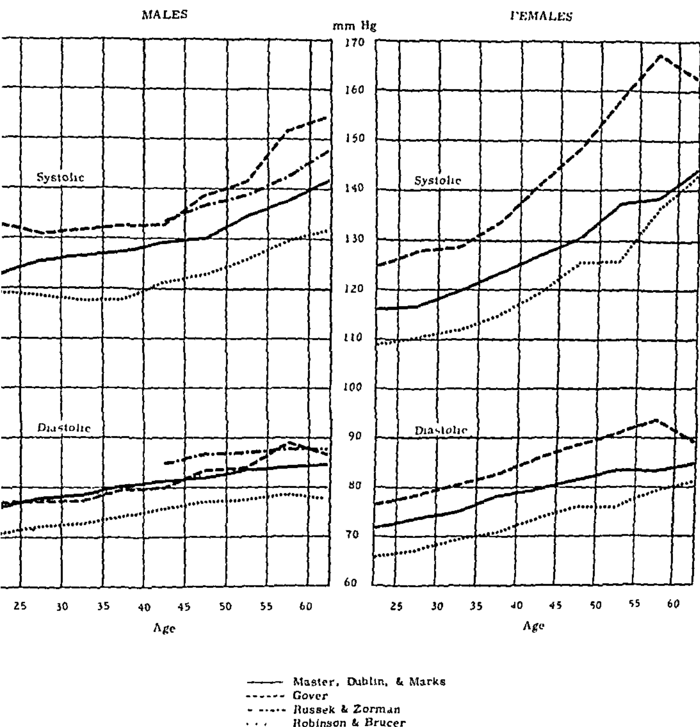
Values are in mm Hg. Values in parentheses are *ranges*, *estimate "b"* (cf. Introduction).

	No and Sex	Age yr	Male Systolic	Male Diastolic	Female Systolic	Female Diastolic	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1		Birth	77	42			1
2		1 da	82	40			
3		2 da	85	43			
4		4 da	91	50			
5		6 mo-1 yr	89(60-118)	60(50-70)[1]			2
6		1	96(66-126)	66(41-91)[1]			
7		2	99(74-124)	64(39-89)[1]			
8		3	100(75-125)	67(44-90)[1]			
9	608♂, 427♀	4	89(78-100)	60(46-74)	89(76-102)	60(47-73)	3
10		5	92(80-104)	62(47-77)	92(79-105)	62(49-75)	
11		6	94(81-107)	64(49-79)	94(80-108)	64(49-80)	
12		7	97(84-110)	65(50-80)	97(83-111)	66(51-81)	
13		8	100(87-113)	67(53-81)	100(86-114)	64(50-78)	
14		9	101(88-114)	68(55-81)	101(87-115)	69(55-83)	
15		10	103(90-116)	69(57-81)	103(89-117)	70(57-83)	
16		11	104(91-117)	70(59-81)	104(90-118)	71(58-84)	
17		12	106(93-119)	71(61-81)	106(92-120)	72(58-86)	
18		13	108(95-121)	72(62-82)	108(95-121)	73(58-88)	
19		14	110(97-123)	73(63-83)	110(97-123)	74(57-91)	
20		15	112(98-126)	75(64-86)	112(98-126)	76(57-95)	
21	7722♂, 7984♀	16	118(95-142)	73(53-93)	116(92-140)	72(54-91)	4
22		17	121(96-146)	74(56-93)	116(93-139)	72(54-90)	
23		18	120(96-143)	74(55-94)	116(94-139)	72(55-89)	
24		19	122(92-151)	75(54-95)	115(92-138)	71(54-89)	
25		20-24	123(96-150)	76(57-96)	116(93-139)	72(53-91)	
26		25-29	125(100-150)	78(60-95)	117(94-139)	74(56-92)	
27		30-34	126(99-153)	79(60-98)	120(92-147)	75(54-96)	
28		35-39	127(99-155)	80(60-101)	124(97-151)	76(58-98)	
29		40-44	129(100-159)	81(63-100)	127(94-161)	80(59-100)	
30		45-49	130(97-163)	82(61-103)	131(92-169)	82(59-104)	
31		50-54	135(97-172)	83(61-106)	137(96-179)	84(59-106)	
32		55-59	138(101-175)	84(62-106)	139(97-180)	84(61-106)	
33		60-64	142(100-183)	85(60-109)	144(100-188)	85(60-110)	
34	2998♂, 2759♀	65-69	143(92-194)	83(64-102)	154(97-211)	85(58-112)	5
35		70-74	145(93-197)	82(52-112)	159(108-210)	85(55-115)	
36		75-79	146(104-188)	81(56-106)	158(106-210)	84(58-110)	
37		80-84	145(95-195)	82(63-101)	157(102-212)	83(57-109)	
38		85-89	145(98-192)	79(50-108)	154(99-209)	82(48-116)	
39		90-94	145(99-191)	78(54-102)	150(104-196)	79(55-103)	
40		95-106	146(92-200)	78(53-103)	149(103-195)	81(57-106)	

/1/ Point of muffling taken as the diastolic pressure

Contributors (a) Master, Arthur M , (b) Van Liere, Edward J., and Hugh A. Lindsay, (c) Hartroft, W. Stanley

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Contributor: Hartroft, W. Stanley

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35		173♂		None	Cuff on tail, systolic by palpation, diastolic by oscillation or auscultation	98(90-104)	64(45-86)		13
36		43♀		None	Cuff on tail; systolic by palpation, diastolic by oscillation or auscultation	90(86-98)	59(43-84)		1
						(90-104)	(54-60)		14
						(60-126)			15
37	Jackass	4		Nembutal or luminal	Cuff, mercury manometer	112(90-125)	81(67-90)		
38	Mouse	15	16-25 g	Urethane or ether	Optical manometer	147(133-160)	106(102-110)		16
39		12		Local		111(95-138)			
40		2		None	Plethysmograph	136(114-165)			
41		19	2.5-5 mo	None	Plethysmograph	151(138-164)		(120-135)	1
42		14	13-14 mo	None	Plethysmograph				17
43		13	31-32 mo			110(95-130)	80(60-90)		18
44	Opossum	32		None	Hamilton manometer	82(70-90)			19
45	Rabbit	9		None	Pressure cup on central artery	120(80-150)			
46				None	Cuff on carotid loop; mercury manometer	35	1		20
47		55			Hypodermic manometer	130(75-150)			21
									c
		1	Newborn		Optical manometer	116(88-130)	90(60-100)		22
48		6²		Nembutal		106(78-132)			21
49	Rat				Plethysmograph	(60-140)			24
50		70	Young adult	Ether	Cuff, foot microscopy			124	
51		100		Nembutal	Mercury manometer			116	22
52		18♂	6 mo	Ether and/or amytal	Mercury manometer	105(87-122)			25
53		23♀	6 mo	Ether and/or amytal	Plethysmograph	120(40-180)			26
54		18	Young adult	Dial	Strain gauge; foot pulse	90(60-120)			
55		68³		Nembutal	Cuff, microscopy	110(80-140)			25
56				Nembutal	Cuff, microscopy	120(45-180)			27
57				Ether	Optical manometer	125(102-140)			
58		68³		Nembutal	Plethysmograph	104(94-112)			
59		40♀	135-200 g	None	Plethysmograph	117(110-126)			
60				Amytal, 4 mg/100 g	Plethysmograph	104(95-110)			
61				Ether, shallow	Plethysmograph	64(62-70)			
62				Ether, deep	Plethysmograph	104(86-115)			
63				Morphine, 10 mg/100 g	Plethysmograph	78(72-84)			
64				Nembutal, 4 mg/100 g	Plethysmograph	129(88-184)	91(58-143)		28
65				Urethane, 20 mg/100 g	Optical manometer	130(108-163)			29
66				Pentobarbital	Aortic cuff; mercury manometer			133⁶	10
67	Rat, Norway	124⁴	Adult	None	Mercury manometer			114(90-140)	5
68	Rat, Sprague-Dawley	20♂⁵	105-106 g					157(98-206)	1
69	Seal (Phoca vitulina)	1	Young	Local		169(144-185)	108(98-120)		f
70	Sheep	13							
71		4							
72	Swine								

/1/ Fasted 7-38 days. /2/ 50 determinations. /3/ Number of determinations. /4/ Mostly male. /5/ 540 determinations. /6/ Approximately.

Contributors. (a) Van Liere, Edward J., and Hugh A. Lindsay, (b) Conklin, Ruth E., (c) Freed, S. Charles, (d) Freis, Edward D., (e) Heisler, Charles R., and Jack R. Leonards, (f) Link, Roger P., (g) Rodbard, Simon, (h) Woodbury, Robert A.

Part II MAMMALS OTHER THAN MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	No and Sex	Age or Weight	Anesthetic	Blood Pressure, mm Hg				Reference
					Method	Systolic	Diastolic	Mean	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Bat	1						50	1
2	Cat	4		None	Cuff on carotid loop; mercury manometer			(140-170)	2
3		2		Barbital	Optical manometer	120	75		
4		3		Ether	Optical manometer	120	75		3
5		191♂	1.4-4.9 kg	Dial-urethane	Mercury manometer			129(67-216)	4
6		208♀	1.4-4.9 kg	Dial-urethane	Mercury manometer			121(62-200)	
7	Cattle					134(124-166)	88(80-120)		1
8		♀		Local				125	5
9		♀		Chloral hydrate				166	6
10		4	Young					157(133-177)	1
11								130(110-140)	c
12			Young	Nembutal				(160-180)	5
13	Dog	67♂		Sodium barbital	Mercury manometer			134(85-190)	7
14		80♀		Sodium barbital	Mercury manometer			125(60-170)	
15						120			c
16		35		None	Hypodermic, Tycos sphygmomanometer			108(92-120)	8
17		13		None	Cuff, auscultation	112(95-136)	56(43-66)		
18		22		Nembutal	Capacitance manometer	156(108-198)	100(75-121)		9
19		22		Nembutal	Oscillometer	149(108-189)	100(75-122)		10
20		22		Nembutal	Auscultation	149(100-187)	104(79-127)		
21		99♂		Morphine	Hypodermic, optical manometer	180(100-275)	89(30-140)		11
22		116♀		Morphine	Hypodermic; optical manometer	180(100-275)	89(30-140)		
23		4							
24		4[1]						159(143-172)	1
25	Goat	2			Cuff; auscultation	82(74-86)	42(35-51)		9
26		4		Urethane				126(118-135)	1
27								120	5
28	Guinea pig					120(112-126)	84(76-90)		f
29	Hamster							75(7-111)	1
30			Adult	Nembutal				(90-100)	c
31	Horse	6	13-18 yr	Local	Mercury or condenser manometer			(120-170)	12
32		5♂	4.5 mo-1.5 yr	None	Cuff on tail, systolic by palpation, diastolic by oscillation or auscultation	80	50	169(152-194)	5
33		3♀	4.5 mo-1.5 yr	None	Cuff on tail; systolic by palpation, diastolic by oscillation or auscultation	80	50		13
34		120				85(70-98)	48(40-58)		1

	Animal	No. of Subjects	Method	Systolic	Diastolic	Mean	Reference
						194	1
18	Kite (Milvus migrans)	4	Local	Optical manometer	135(120-140)	105(100-115)		2
19	Pigeon	2	Local	Optical manometer	118(110-125)	80		2
20	Robin	3	Local	Optical manometer	108(80-135)			2
21	Sparrow, pin-feather	2	Local	Optical manometer	123(115-130)			
22	Fledgling	1	Local	Optical manometer	180	140		
23	Adult	2	Local	Optical manometer	180(150-210)	130(100-160)		2
24	Starling						161	1
25	Stork						193	1
26	Turkey						171	1
27	Vulture							

/1/ 3 breeds

Contributors (a) Van Liere, Edward J., and Hugh A. Lindsay, (b) Conklin, Ruth E., (c) Freed, S. Charles, (d) Freis, Edward D., (e) Heisler, Charles R., and Jack R. Leonards, (f) Rodbard, Simon, (g) Woodbury, Robert A.

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Part IV REPTILES AND AMPHIBIANS

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal (A)	No. of Subjects (B)	Method (C)	Blood Pressure, mm Hg: Systolic (D)	Diastolic (E)	Mean (F)	Reference (G)
1	Crocodile					(30-55)	1
2	Snake, ring					89	1
3	Turtle	11	Optical manometer	44(38-55)	37(28-47)		2
4	Turtle (Pseudemys elegans)[1]		Hamilton manometer	31	25		3
5	Turtle (P. elegans)[2]		Hamilton manometer	27	21		3
6	Turtle (P. rugosa)					(18-37)	1
7						(18-35)	1
8	Frog			(30-55)			1
9				(20-60)			1
10	Frog (Rana catesbeiana)					(5-30)	1
11		6[3]	Optical manometer	43(36-56)	31(24-44)		2
12		6[4]	Cuff; web microscopy	32(28-36)	21(18-24)		4
13	Frog (R. pipiens)	6[4]	Cuff, web microscopy	31(21-36)	21(16-26)		4
14	Toad, earth					48	1

/1/ At 22°C. /2/ At 16°C. /3/ Local anesthesia. /4/ No anesthesia.

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Part II· MAMMALS OTHER THAN MAN (Concluded)

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Part III: BIRDS

Values in parentheses are ranges, estimate "c" (*cf.* Introduction).

	Animal	No. of Subjects	Anesthetic	Blood Pressure, mm Hg				Reference
				Method	Systolic	Diastolic	Mean	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Buzzard (Buteo buteo)							
2	Canary	6					171	1
3	Chicken[1]	5	Barbital	Optical manometer	175(110-250)	154(150-160)		2
4		1	Morphine	Optical manometer	130	85		3
5		1	Ether	Optical manometer	130	85		3
6	Chicken, ♂	13		Optical manometer	130	85		3
7	Chicken, ♀						135	4
8	Crow (Corvus cornix)						(88-171)	1
9	Crow (C frugilegus)						147	1
10	Duck, domestic						151	1
11	Duck, wild						162	1
12	Falcon (Falco cenchris)						179	1
13	Fowl						103	1
14	Goose				150	120		1
15	Gull (Larus canus)							f
16	Hawk (Astur						(129-176)	1
	palumbarius)						179	1
17	Jackdaw (Corvus						178	1
	monedula)						119	1

54. CAPILLARY BLOOD PRESSURE: VERTEBRATES

All measurements made directly by microcannulation [8] Capillary A = arterial, V = venous. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Tissue	Animal	Condition	Capillary	Blood Pressure mm Hg	Blood Pressure cm H_2O	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Eponychium (finger)	Man	Normal	A	30 6(7.5-60.0)		1
2				V	21.9(7.5-47.0)		
3		Man	Normal	A	29 3(13.9-44.4)[1]	43.5(28 6-65 0)[1,2]	E,2,F,2,3
4				V	14 1(8.3-19.9)[1]	16 5(8 0-24 5)[1,2]	
5		Man	Hypertension	A	35 9(7.5-70.5)		1
6				V	22.8(9.5-43 0)		
7		Man	Hyperemia	A		86(71.0-93 0)	3
8				V		(54 5-66.5)	
9	Mesentery	Guinea pig		A	28.0(23 0-36.0)	38.5(31 0-49.0)[3,4]	E,4,F,3,5
10				V	12.0(9.5-14 5)	17.0(13.0-19.5)[3,4]	
11		Rat		A	22.0(16 0-25.0)	30 0(22 0-34 0)[3]	E,6;F,3,5
12				V	12.7(11 0-14 5)	17.0(15.0-20 0)[3]	
13		Frog		A		14.4(5.0-22 0)[5]	3,4
14				V		10.1(6.7-18 0)[5]	
15	Muscle	Frog	Normal	A	10 7(8.1-13.2)	14 9(11.0-18 0)[6]	E,5,7,F,3,7
16				V	7.1(5 1-9.2)	9.5(7 0-12 7)[6]	
17		Frog	Hyperemia	A		20.1(17.0-26 0)	3
18				V		16 0(12 0-17 5)	
19	Web	Frog	Normal	A	10 2(8.1-13.2)	13.9(10.0-19.0)[6]	E,7;F,3,7
20				V	8.1(5 9-10.3)	9 6(8.5-13.0)[6]	
21		Frog	Normal	A		14 5(10.0-20.5)[7]	3
22				V		10 0(8 5-15.5)[7]	
23		Frog	Hyperemia	A		19.5(14.0-26.5)	3
24				V		16 5(15 0-17.5)	

/1/ Varies directly with arteriolar vasodilatation produced by emotion, heat, or trauma. Varies inversely with arteriolar vasoconstriction produced by emotion or cold. Varies minimally in a single capillary with time, and also from capillary to capillary. /2/ Varies directly with venous pressure as affected by hydrostatic pressure or venous obstruction. /3/ Decerebrate. /4/ Anesthetized (veronal ether). /5/ Pithed. /6/ Anesthetized (urethane). /7/ Curarized

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55 VENOUS BLOOD PRESSURE. MAN

Reference level is the phlebostatic axis Subjects in supine position, breathing quietly Forced respiration (e.g., Valsalva's maneuver) profoundly influences venous pressure. Values in parentheses are ranges, estimate "c" (cf. Introduction)

	Vein	Blood Pressure mm H_2O
	(A)	(B)
	Median basilic vein at elbow	
1	3-5 yr	46(30-63)
2	5-10 yr	58(33-74)
3	Adult ♀	94(60-128)
4	Adult ♂	100(50-140)
5	Femoral	111(98-128)
6	Abdominal	115(70-160)
7	Dorsal metacarpal	130(70-170)
8	Great saphenous at ankle	150(110-190)
9	Dorsal pedal	175(124-210)

Contributor Terry, Luther L.

Reference Burch, G. E 1950 A primer of venous pressure. Lea and Febiger, Philadelphia

Part V: FISHES

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	Blood Pressure, mm Hg			Reference
		Systolic	Diastolic	Mean	
	(A)	(B)	(C)	(D)	(E)
1	Barbel			42	1
2	Carp[1]	43(40-45)			2
3	Eel			(65-70)	1
4	Pike			(35-84)	1
5	Ray (Raja sp)	20			1
6		21			1
7	Ray (R. punctulata)	16	7		3
8	Ray, electric			(16-18)	1
9	Salmon			75(47-120)	1
10	Shark, cat	(8-9)			3
11		33	29		3
12				(30-37)	1

/1/ 3 fish under local anesthesia; values derived by optical manometer method

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Part VI: INVERTEBRATES

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	Blood Pressure, mm Hg		Reference
		Systolic	Mean	
	(A)	(B)	(C)	(D)
1	Crab	4		1
2	Lobster		9	1
3	Lobster (Homarus sp)	10		1
4	Mussel (Anodonta sp)	3		2
5	Octopus (Octopus sp)		(25-80)	1
6	Octopus (O. vulgaris)	60		1
7	Sea hare (Aplysia sp)	(20-40)		3
8	Squid	(25-80)		1

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56. PULSE CHARACTERISTICS: MAN (Concluded)

Part II: PULSE WAVES

	Chamber or Vessel	Method	Maximal Velocity m/sec	No. of Waves	Wave Configuration	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Right atrium	Right heart catheterization.		2	Small, positive wave in presystole; collapse during ventricular systole, positive wave at the opening of tricuspid valve; collapse in early diastole.	1-5
2	Left atrium	Left heart catheterization.		2	Small, positive wave in presystole, collapse during ventricular systole; positive wave at opening of mitral valve; collapse in early diastole	5,6
	ventricle	or retrograde arterial catheterization.			lar systole, plus smaller vibrations.	
5	Pulmonary arteries	Right heart catheterization, or by electrokymography.	2	1	1 positive wave during ventricular systole.	4,8
6	Pulmonary arterioles	Right heart catheterization, or by electrokymography	2.75	2	1 in early systole and 1 in early diastole.	4,8
7	Pulmonary veins	Left heart catheterization, or deduced from animal experimentation and from collateral data in man.[1]		2	Small, positive wave in presystole; collapse during ventricular systole; positive wave at opening of mitral valve; collapse in early diastole.	3-5
8	Aortic arch	Retrograde arterial catheterization, or indirect pulse tracing	4(3-5)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave).	4,9-12
9	Thoracic aorta	Retrograde arterial catheterization, or indirect pulse tracing	5(4-6)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave).	4,9-12
10	Abdominal aorta	Retrograde arterial catheterization, or indirect pulse tracing.	6(5-7)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave).	4,9-12
11	Carotid arteries	Indirect pulse tracing, or deduced from animal experimentation and from collateral data in man.	5(4-6)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave)	4,11-13
12	Femoral arteries	Direct measurement, or indirect pulse tracing.	6(5-8)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave).	4,11-14
13	Bronchial arteries	Direct measurement, or indirect pulse tracing.	6(5-8)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave).	4,11-14
14	Tibial arteries	Direct measurement, or indirect pulse tracing.	8(6-10)	2	1 positive wave in systole, plus small wave in early diastole (dicrotic wave).	4,11-14
15	Jugular veins	Indirect pulse tracing	1 5	3	Small, positive wave in presystole, plus small wave in systole; collapse during ventricular systole, positive wave at opening of tricuspid valve, collapse in early diastole	4,12,13
16	Venae cavae	Right heart catheterization.		2	Small positive wave in presystole, collapse during ventricular systole; positive wave at opening of tricuspid valve, collapse in early diastole.	4,12,13

/1/ In cases of atrial septal defect

Contributor: Luisada, Aldo A.

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al. 1950 J Clin. Invest 29 602 {3} Lagerlöf, H., and L. Werkö. 1949 Scand J Clin. &c. Invest., Oslo 1:147.
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Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I. BLOOD PRESSURES

	Chamber or Vessel	Method	Ventricular Pressure Systolic mm Hg	Ventricular Pressure Diastolic mm Hg	Mean Pressure mm Hg	Pulse Pressure mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
		retrograde arterial catheterization, or indirect measurement.[1]					
5	Pulmonary artery	Right heart catheterization.	20(11-29)	9(4-13)	(8-19)	(7-16)	3
6	Pulmonary arterioles[2]	Right heart catheterization.	15	5	(5-13)	10	3-7
7	Pulmonary veins	Left or right heart catheterization[1], or deduced from animal experimentation and from collateral data in man.	4	8	5(3-8)		9, 14
8	Aorta	Retrograde arterial catheterization, or left heart catheterization.	120(100-150)	70(60-90)	95	50	11
9	Carotid arteries	Deduced from animal experimentation and from collateral data in man.	120	70	95	50	12, 14
10	Femoral arteries	Direct or indirect measurement.	150	80	115	70	15-17
11	Bronchial arteries	Direct or indirect measurement.	120	80	100	40	13, 15
12	Tibial arteries	Direct or indirect measurement.	140	80	110	60	12, 14, 15
13	Small veins	Deduced from animal experimentation and from collateral data in man			18(15-20)		18
14	Medium veins	Direct measurement.			5(3.5-7.0)		12, 14, 18
15	Venae cavae	Right heart catheterization.			-1(-5 to +4)		12, 17

/1/ In cases of atrial septal defect. /2/ "Pulmonary capillary" pressure or "wedge pressure."

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58. CIRCULATION TIME: VERTEBRATES

Circulation time = time required for an indicator substance introduced into the blood stream to traverse a particular vascular circuit. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)
	Man (Newborn)			
1	Arm to conjunctiva (first 5 da of life)	Fluorescein	10.2(5-14)	1
2	*Ductus venosus* to lips	Fluorescein	4.4(3.3-6.0)	2
3	Umbilical vein to lips	Fluorescein	4.8(3.1-7.0)	2
4	Wrist to eye	Fluorescein	7.8(5-10)	3
	Man (Child)			
5	Arm to arm	Radioactive sodium	11(5-17)	4
6	Arm to arm (14 da-6 yr)	Riboflavin	8.9(6.2-15.1)	5
7	Arm to arm (6-13 yr)	Riboflavin	10.4(9.2-15.3)	5
8	Arm to carotid sinus	Sodium cyanide	(9.0-13.5)	6
9	Arm to foot	Riboflavin	28.1(25-35)	5
10	Arm to lips (1-24 mo)	Fluorescein	7.0(5.0-9.1)	7
11	Arm to lips (4-24 mo)	Fluorescein	6.5(5 0-8.5)	8
12	Arm to lips (2-13 yr)	Fluorescein	11.5(7-16)	7
13	Arm to lips (3-13 yr)	Fluorescein	8.5(5.0-12.5)	8
14	Arm to lips (5-10 yr)	Fluorescein	10	9
15	Arm to mouth (4-24 mo)	Fluorescein	6(4 5-7 5)	10
16	Arm to mouth (2-4 yr)	Fluorescein	6.5(5.5-7.5)	10
17	Arm to mouth (4-7 yr)	Fluorescein	8(6.5-9.5)	10
18	Arm to mouth (7-12 yr)	Fluorescein	10.7(8.5-13 0)	10
19	Arm to mouth (12-15 yr)	Fluorescein	12(10.1-14.0)	10
20	Arm to opposite brachial artery (birth-2 yr)	Radioactive sodium	7(3-12)	4
21	Arm to tongue or nose	Thiamine HCl	(4-8)	11
22	Wrist to eye (2-12 mo)	Fluorescein	10(7.6-13.0)	3
	Man (Adult)			
23	Antecubital vein to radial artery	Evans' blue (T-1824)	17.5(14.5-23 0)	12
24	Arm to arm	Brilliant vital red	(30-45)	13
25	Arm to arm	Congo red	(8-12)	14
26	Arm to arm (♂, rest)	Evans' blue (T-1824)	18.2(14.3-24.3)	15
27	Arm to arm (♂, exercise)	Evans' blue (T-1824)	12.1(9.5-17.9)	15
28	Arm to arm (♀, rest)	Evans' blue (T-1824)	15.4(10.2-20.2)	15
29	Arm to arm (♀, exercise)	Evans' blue (T-1824)	9.9(7.3-11.5)	15
30	Arm to arm (rest)	Evans' blue (T-1824)	22 5(17-29)	16
31	Arm to arm (exercise)	Evans' blue (T-1824)	20.2(14-26)	16
32	Arm to arm (42-58 yr, rest)	Evans' blue (T-1824)	18 4(10.3-24 8)	17
33	Arm to arm (42-58 yr, exercise)	Evans' blue (T-1824)	12.3(9.8-16.1)	17
34	Arm to arm	Evans' blue (T-1824)	30.1(22.4-37.8)	18
35	Arm to arm	Evans' blue (T-1824)	19	19
36	Arm to arm	Fluorescein	16.6(9-25)	20
37	Arm to arm (15-79 yr)	Fluorescein	(12-26)	21
38	Arm to arm	Fluorescein	18.6(13.5-25.6)	5
39	Arm to arm	Radium-C	18(12-23)	22
40	Arm to arm (13-65 yr)	Riboflavin	19.1(14.5-26 2)	5
41	Arm to arm	Thorium-X	(10-20)	23
42	Arm to brain (semirecumbent subject)	Thiopental	13(10-16)	24
43	Arm to carotid sinus	Lobeline	10 6	25
44	Arm to carotid sinus	Lobeline	8.5(5.0-12 5)	26
45	Arm to carotid sinus	Lobeline	8.3(5-12)	27
46	Arm to carotid sinus	Lobeline	9.5(7-12)	28
47	Arm to carotid sinus	Lobeline	10.3(7-15)	29
48	Arm to carotid sinus	Lobeline	9.9(6.4-13 5)	30, 31
49	Arm to carotid sinus	Sodium cyanide	20 1(12-33)	32
50	Arm to carotid sinus	Sodium cyanide	15 6(12.5-18.0)	33
51	Arm to carotid sinus	Sodium cyanide	15 6(9-21)	34
52	Arm to carotid sinus	Sodium cyanide	17(7-92)	35
53	Arm to carotid sinus	Sodium cyanide	20.1(12.4-33.2)	36
54	Arm to carotid sinus (warm subject)	Sodium cyanide	18.5(13-27)	37
55	Arm to carotid sinus (cold subject)	Sodium cyanide	32.3(25-47)	37
56	Arm to carotid sinus (pregnant)	Sodium cyanide	14 5(10-24)	38

57. HEART PRESSURES: MAN

Part I: BIRTH TO TWO WEEKS

Additional values for some of the variables are available in the literature [2, 4]. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Pressure	Right Heart: No. of Subjects	Right Heart: Value mm Hg	Left Heart: No. of Subjects	Left Heart: Value mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Atrium					
1	Systolic	8	0(-6 to +4)	5	1.6(-2 to +10)	1
2	Diastolic	8	-2(-8 to +2)	5	-0.4(-4 to +9)	1
3	Mean		(0-3)		(1-4)	2
	Ventricle					
4	Systolic	8	35(20-48)			1
5	Diastolic	8	0(-10 to +8)			1
	Pulmonary artery					
6	Systolic	13	41(16-80)			1,3
7	Diastolic	13	20(0-50)			1,3
8	Mean[1]	6	36(17-45)			3
	Femoral artery[2]					
9	Systolic			6	72(55-90)	3
10	Diastolic			6	46(20-65)	3
11	Mean[1]			5	54(40-80)	3

/1/ Electrically derived. /2/ Pressures obtained by direct puncture.

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Part II: ADULTS

Additional values for some of the variables are available in the literature [8-11]. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Pressure	Right Heart: No. of Subjects	Right Heart: Value mm Hg	Left Heart[1]: No. of Subjects[2]	Left Heart[1]: Value mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Atrium[3]					
1	Mean	24	2.8(1-5)	5	7.4(4-10)	B, C, 1, 2, D, E, 3, 4
2	A wave	9	5.6(2.5-7)	3	8.7(6-12)	B, C, 1, D, E, 3, 4
3	X wave	7	2.9(1-5.5)			1
4	C wave	5	3.8(1.5-6)	3	8.7(6-12)	B, C, 1, D, E, 3, 4
5	X' wave	8	1.7(0-5)			1
6	V wave	7	4.6(2-7.5)	4	10.3(7-14)	B, C, 1, D, E, 3, 4
7	Y wave	7	2.4(0-6)			1
	Ventricle					
8	Peak systolic	33	24.7(17-32)	6	90.2(79-121)	B, C, 1, 2, 5, D, E, 3, 4
9	End diastolic	13	4(1-7)	6	8.8(4-14)	B, C, 2, D, E, 3, 4
10	Mean diastolic			6	6.2(3-10)	3, 4
	Pulmonary artery					
11	Mean	31	14.7(9-19)			1, 2
12	Peak systolic	51	22.3(11-29)			1, 2, 6, 7
13	End diastolic	51	8.7(4-13)			1, 2, 6, 7
14	Pulmonary wedge ("capillary")	24	8.6(4.5-13)			1, 7

/1/ Zero point, mid-atrial level. /2/ Studies performed on anesthetized, open-chest patients. /3/ For atrial configurations, see p. 156.

Contributor. Fowler, Noble O.

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	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)
	Man (Adult) (continued)			
118	Arm to medulla	Papaverine	20.8(15.4-27.0)	69
119	Arm to mouth	Calcium chloride	(9-16)	70
120	Arm to palpebral muscle	Succinylcholine	22.7(15-32)	71
121	Arm to perineum	Macasol	26(9.2-42 8)[b]	53
122	Arm to perineum	Macasol	21.5(12-32)	52
123	Arm to perineum	Macasol	21.2(10-34)	54
124	Arm to rectum	Fluorescein	20(19-21)	41
125	Arm to respiratory center (♂, 60-95 yr)	Lobeline	12.8	72
126	Arm to respiratory center (♀, 60-95 yr)	Lobeline	16.6	72
127	Arm to respiratory center	Sodium succinate	15.8(12.0-19.5)	73
128	Arm to respiratory center (student)	Sodium succinate	20(16.1-26.1)	74
129	Arm to respiratory center (trained athlete)	Sodium succinate	27.3(20.5-43 2)	74
130	Arm to respiratory center	Theophylline ethylenediamine	12.1(6.8-22.0)	75
131	Arm to respiratory center	Theophylline ethylenediamine	12.5(10-15)	76
132	Arm to throat	Calcium gluconate	18(12-25)	43
133	Arm to throat	Magnesium sulfate	(11-17)	77
134	Arm to throat	Macasol	13 8(7-22)	78
135	Arm to tongue	Calcium bromide	(10-17)	79
136	Arm to tongue	Calcium gluconate	(10.0-16.6)	80
137	Arm to tongue	Calcium gluconate	(7.1-24 0)	81
138	Arm to tongue	Calcium gluconate	12.7(8-16)	64
139	Arm to tongue	Calcium gluconate	12.1(10.3-15.3)	82
140	Arm to tongue (pregnant, 1st trimester)	Calcium gluconate	12 4(10.3-15.0)	83
141	Arm to tongue (pregnant, 2nd trimester)	Calcium gluconate	11.3(9.2-15.4)	83
142	Arm to tongue (pregnant, 3rd trimester)	Calcium gluconate	10.2(8.0-16.2)	83
143	Arm to tongue	Decholin	12.3(10-14)	84
144	Arm to tongue (pregnant)	Decholin	14 7(12.5-17.5)	84
145	Arm to tongue (recumbent subject)	Decholin	14(10-17)	24
146	Arm to tongue (semirecumbent subject)	Decholin	9(7-11)	24
147	Arm to tongue	Decholin	27.3(9-63)	39
148	Arm to tongue	Decholin	13.6(8.0-25.4)	85
149	Arm to tongue	Decholin	13.4(10-18)	86
150	Arm to tongue	Decholin	22.9(13-31)	87
151	Arm to tongue	Decholin	(7.4-19.0)	81
152	Arm to tongue	Decholin	(10-15)	88
153	Arm to tongue	Decholin	(8-14)	89
154	Arm to tongue	Decholin	18(15-20)	33
155	Arm to tongue	Decholin	13(10-16)	90
156	Arm to tongue	Fluorescein	15 6(10.8-21.0)	80
157	Arm to tongue	Intra-sul (sulfur and salts)	11.6(10-17)	65
158	Arm to tongue	Macasol	17.2(11-27)	58
159	Arm to tongue	Macasol	14 6(7-22)	52
160	Arm to tongue	Macasol	13.7(5-24)	54
161	Arm to tongue	Macasol	16.7(7.1-26.3)[b]	53
162	Arm to tongue (♂)	Magnesium sulfate	19.1(8.7-29.5)[b]	44
163	Arm to tongue (♀)	Magnesium sulfate	16.1(5 5-26.7)[b]	44
164	Arm to tongue	Magnesium sulfate	12.9(7.0-17.8)	91
165	Arm to tongue	Magnesium sulfate	(10.0-20.8)	80
166	Arm to tongue	Saccharin	12.6(7.5-36.0)	64
167	Arm to tongue	Saccharin	26.1(15-60)	39
168	Arm to tongue	Saccharin	11.9(9.0-15.8)	92
169	Arm to tongue	Saccharin	10.7(6-18)	62
170	Arm to tongue	Saccharin	(11.8-31.8)	93
171	Arm to tongue	Thiamine HCl	(5-13)	11
172	Foot to carotid sinus	Sodium cyanide	27.7(19-40)	34
173	Foot to carotid sinus	Sodium cyanide	36(15-95)	35
174	Foot to carotid sinus	Sodium cyanide	38.7(22-67)	32,36
175	Foot to foot	Fluorescein	27.2(21-35)	20
176	Foot to groin	Radioactive sodium	18(16.2-19.8)[b]	94
177	Foot to groin	Radioactive sodium	21	95
178	Foot to groin (pregnant, 36 wk)	Radioactive sodium	36.8	96
179	Foot to groin (in labor)	Radioactive sodium	50.3	96
180	Foot to groin (puerperium)	Radioactive sodium	15.8	96

	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)
	Man (Adult) (continued)			
57	Arm to cheek	Fluorescein	20.7(9-47)	39
58	Arm to conjunctiva	Fluorescein	10(7.0-15.6)	40
59	Arm to conjunctiva	Fluorescein	9(8-11)	41
60	Arm to conjunctiva	Fluorescein	11	42
61	Arm to ear	Evans' blue (T-1824)	14.2(10-21)	43
62	Arm to ear (♂)	Evans' blue (T-1824)	15.8(6.4-25.2)[b]	44
63	Arm to ear (♀)	Evans' blue (T-1824)	13.2(3.4-23.0)[b]	44
64	Arm to ear	Methylene blue[1]	(9-16)	45
65	Arm to face	Evans' blue (T-1824)	10.5(8 9-12.1)	46
66	Arm to face	Histamine	23(13-30)	47
67	Arm to face	Indigo carmine	9.1(6.6-11.6)	46
68	Arm to face	Methylene blue	12.9(10.8-15.0)	46
69	Arm to femoral artery (♂, sea level)	Evans' blue (T-1824)	16.5(11.2-21.5)	48
70	Arm to femoral artery (♀, sea level)	Evans' blue (T-1824)	15.3(11.1-23.0)	48
71	Arm to femoral artery (♂, high altitude)	Evans' blue (T-1824)	20.7(15.1-27.5)	48
72	Arm to femoral artery	Sodium I^{131}	11.2(5.5-18.5)	49
73	Arm to foot	Fluorescein	27.2(21-35)	20
74	Arm to foot	Fluorescein	23	41
75	Arm to foot	Fluorescein	24.9(21-33)	50
76	Arm to foot	Fluorescein	(34-36)	42
77	Arm to foot	I^{131} albumin	20	51
78	Arm to foot	Macasol	28(10-48)	52
79	Arm to foot	Macasol	37.4(18 4-56.4)[b]	53
80	Arm to foot	Macasol	34(15-59)	54
81	Arm to foot	Radioactive sodium	45(15-90)	55
82	Arm to foot	Riboflavin	28.1(25-35)	5
83	Arm to hand	Fluorescein	(23-28)	42
84	Arm to hand	Fluorescein	24.3(21-30)	50
85	Arm to hand	Macasol	26	52
86	Arm to hand	Macasol	28.1(14.9-41.3)[b]	53
87	Arm to hand	Macasol	23.6(10-39)	54
88	Arm to left ventricle	Diodrast	8(6-9)	56
89	Arm to left ventricle	Diodrast and fluorodensograph	5.6(4.4-6.9)	57
90	Arm to right atrium (17-39 yr)	Radium-C	6.4(3-14)	22
91	Arm to right atrium (40-65 yr)	Radium-C	7.3(4-13)	22
92	Arm to right ventricle	Diodrast and fluorodensograph	1.6(1.3-2.1)	57
93	Arm to heart	Radium-C	6.7(2-14)	22
94	Arm to heart	Sodium I^{131}	1.8(0.8-5.0)	49
95	Arm to lips (10-25 yr)	Fluorescein	20	9
96	Arm to lips (25-60 yr)	Fluorescein	25	9
97	Arm to lips	Fluorescein	(13.0-20.9)	41
98	Arm to lips (20-30 yr)	Fluorescein	15.4	41
99	Arm to lips (30-40 yr)	Fluorescein	15.8	41
100	Arm to lips (40-50 yr)	Fluorescein	16.3	41
101	Arm to lips (50-70 yr)	Fluorescein	17.0	41
102	Arm to lips (70 yr and over)	Fluorescein	18.2	41
103	Arm to lips (exercise)	Fluorescein	6	41
104	Arm to lips	Fluorescein	9	42
105	Arm to lung (recumbent or semirecumbent subject)	Ether	6(4-8)	24
106	Arm to lung	Ether	8(6-12)	58
107	Arm to lung	Ether	5.5(3-8)[b]	59
108	Arm to lung	Ether	(4-8)	60
109	Arm to lung	Ether	(6-9)	61
110	Arm to lung	Ether	6.5(4-8)	28
111	Arm to lung	Ether	6 3(2-11)	62
112	Arm to lung	Ether	7.2(3-12)	63
113	Arm to lung	Ether	5.7(4.1-9.0)	64
114	Arm to lung	Intra-sul (sulfur and salts)	7.1(4-10)	65
115	Arm to lung	Paraldehyde	6(2.8-9.3)[b]	66
116	Arm to medulla	Aminophyllin	12.4(7.1-20.4)	67
117	Arm to medulla	Aminophyllin	14.6(12-19)	68

/1/ Photoelectric method.

	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)
	Dog (concluded)			
238	Right external jugular to left carotid		3 7(3 0-4.4)	123
239	Right external jugular to left external jugular vein		9.3	123
240	Right external jugular to left external jugular vein	Lithium acetate[3]	7.8(4.9-10 2)	114
241	Right heart to left heart	Shadacol	5.5	119
242	Right ventricle to sino-atrial node	Acetylcholine	6(4.4-6.8)	121
243	Root of aorta to sino-atrial node	Acetylcholine	1.3(1.1-1.7)	121
244	Superior vena cava to sino-atrial node	Acetylcholine	7.8(6 4-9.9)	121
245	2-3 cm above root of aorta to sino-atrial node	Acetylcholine	3.4(2.6-4.3)	121
246	Total circulation		(8.9-12.8)	122
247	Total circulation	Thiocyanate	(10-11)	120
	Rabbit			
248	Ear vein to carotid sinus	Sodium cyanide	3.9	114
249	Ear vein to ear vein	Methylene blue	6	
250	Ear vein to ear vein	Lithium chloride	4.7	114
251	Ear vein to eye	Fluorescein	(5-6)	124
252	Ear vein to medulla	Sodium cyanide	3 9(3.3-5.2)	114
253	Femoral artery to femoral vein		3.8	123
254	Femoral vein to right atrium	Bismuth oil	6	118
255	Jugular vein to crural vein		8.4	123
256	Left jugular vein to right femoral artery	Sodium chloride	(3.3-4 5)	123
257	Left jugular vein to right jugular vein	Sodium chloride	(4.1-6.1)	123
258	Left jugular vein to right renal artery	Sodium chloride	(3.8-5.4)	123
259	Left jugular vein to right renal vein	Sodium chloride	(10.8-12.7)	123
260	Portal circulation		(3.9-7.0)	123
261	Pulmonary circulation		2.9	123
262	Renal circulation		8	123
263	Right jugular vein to right carotid artery	Sodium chloride	(2.4-3 4)	123
264	Total circulation		10.5	123
	Sheep			
265	Brachocephalic artery to anterior caval channel	Iodine	(5-8)	125
266	Pulmonary circulation, fetal (ductus open)	Iodine	2.7(2-6)	126
267	Pulmonary circulation, at birth (ductus closed)	Iodine	1.4(1.0-3.3)	126
	Chicken			
268	Sciatic vein to arterioles in systemic circuit (normal body temp , 41.5°C)	Acetylcholine	2.8(1.3-5.0)	127
269	Sciatic vein to arterioles in systemic circuit (body temp., 45°C)	Acetylcholine	1.2	127
270	Sciatic vein to arterioles in systemic circuit (body temp., 35°C)	Acetylcholine	4 0	127
271	Sciatic vein to arterioles in systemic circuit (body temp , 30°C)	Acetylcholine	8 2	127
272	Sciatic vein to arterioles in systemic circuit (body temp., 25°C)	Acetylcholine	12.2	127

/3/ Also hexamethylene tetramine

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	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)
	Man (Adult) (concluded)			
181	*Foot to lung*	Ether	(16-34)	59
182	Foot to lung	Ether	32.5(22-40)	97
183	Foot to tongue	Decholin	47.3(26-100)	97
184	Foot to tongue (prone position)	Histamine	37.2(18-72)	98
185	Hand to axilla (puerperium)	Radioactive sodium	11.7	96
186	Lung to ear	Helium	4.6(3-6)	58
187	Lung to ear	Oxyhemoglobin[2]	5.2(4.8-7.1)	99
188	Lung to ear	100% nitrogen	5.2(4.1-7.0)	100
189	Lung to face	Amyl nitrite	19.5(14-25)	79
190	Lung to face (10-20 yr)	Amyl nitrite	17.4	79
191	Lung to face (20-30 yr)	Amyl nitrite	18.4	79
192	Lung to face (30-40 yr)	Amyl nitrite	18.0	79
193	*Lung to face (40-50 yr)*	*Amyl nitrite*	20.0	79
194	Lung to face (50-60 yr)	Amyl nitrite	21.7	79
195	Lung to face (60-70 yr)	Amyl nitrite	21.7	79
196	Lung to face (70 yr and over)	Amyl nitrite	24.0	79
197	Lung to medulla	Carbon dioxide	(11.5-16.5)	101
198	*Lung to medulla*	Carbon dioxide	(5-10)	102
199	Pulmonary artery to brachial artery	Evans' blue (T-1824)	11(10-15)	12
200	Pulmonary artery to brachial artery	*Evans' blue (T-1824)*	11.5(6.1-16.9)[b]	103
201	Pulmonary artery to right ventricle	P^{32}-labelled cells	(7.0-8.5)	104
202	Pulmonary circulation, right atrium to brachial artery (17-39 yr)	Radium-C	10.7(6.5-17.0)	22
203	Pulmonary circulation, right atrium to brachial artery (40-65 yr)	Radium-C	12.9(7.5-17.5)	22
204	Pulmonary circulation, right ventricle to left ventricle	Thorotrast	1.7(1.4-2.5)	105
205	Portal circulation, rectum to lung	Ether	(11-25)	106
206	Portal circulation, rectum to lung	Ether	(20-25)	107
207	*Right heart to abdominal aorta*	*Evans' blue (T-1824)*	7.8(6.6-9.0)	108
208	Right heart to dorsalis pedis	Evans' blue (T-1824)	17.6(12.8-22.2)	108
209	Right heart to ear	Evans' blue (T-1824)	8(6.3-9.3)	108
210	Right heart to femoral artery	Evans' blue (T-1824)	9.7(7.5-10.7)	108
211	Right heart to radial artery	Evans' blue (T-1824)	10.7(8.6-13.6)	108
212	*Thoracic aorta to abdominal aorta*	*Evans' blue (T-1824)*	1.5(0.9-2.1)	108
213	Thoracic aorta to dorsalis pedis	Evans' blue (T-1824)	11.8(8.1-22.3)	108
214	Thoracic aorta to ear	Evans' blue (T-1824)	21.5(18.3-35.2)	108
215	Thoracic aorta to femoral artery	Evans' blue (T-1824)	2.9(1.8-3.8)	108
216	Thoracic aorta to radial artery	Evans' blue (T-1824)	24.3(20.3-36.5)	108
217	Total circulation	P^{32}-labelled cells	(7-9)	104
	Cat			
218	*Femoral vein to carotid artery*		(3.0-3.5)	109
219	Femoral vein to carotid artery	P^{32}-labelled cells	(3-5)	110
220	Femoral artery to carotid artery	P^{32}-labelled cells	(9-11)	110
221	Femoral artery to femoral vein	P^{32}-labelled cells	(4-8)	110
222	Left common carotid to right atrium	Radium-C	6(3.0-9.5)	111
223	*Subclavian vein to carotid artery*	I^{131}-albumin-labelled plasma	11.2	112
224	Subclavian vein to carotid artery	P^{32}-labelled cells	9.6	112
	Cow			
225	Mammary vein to opposite mammary vein	Fluorescein	52	113
	Dog			
226	*External jugular vein to carotid sinus*	Sodium cyanide	8.7(5.4-13.8)	114
227	Femoral vein to carotid sinus	Sodium cyanide	11.7(8-16)	115
228	Femoral vein to carotid sinus	Sodium cyanide	(6-15)	116
229	Femoral vein to conjunctiva	Fluorescein	12.6(9-16)	117
230	Femoral vein to right atrium	Bismuth oil	(16-18)	118
231	*Jugular vein to right heart*	Shadacol	(1.0-2.5)	119
232	Left heart to right heart	Shadacol	6	119
233	Left ventricle or aorta to femoral artery	Thiocyanate	4	120
234	Left ventricle (apex) to sino-atrial node	*Acetylcholine*	1.8(1.7-2.1)	121
235	Leg vein to sino-atrial node	Acetylcholine	6.7(4.0-9.5)	121
236	*Main pulmonary artery to sino-atrial node*	Acetylcholine	5.2(3.9-7.6)	121
237	Pulmonary circulation (lesser circuit)		(4.6-6.2)	122

/2/ Measured with Millikan oximeter.

58. CIRCULATION TIME: VERTEBRATES (Concluded)

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59. CIRCULATION TIME IN PATHOLOGIC CONDITIONS. MAN

Circulation time = time *required for* an indicator substance introduced into the blood stream to traverse a particular vascular circuit. Values in parentheses are *ranges*, estimate "c" unless otherwise indicated (cf. *Introduction*).

	Condition	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)	(E)
1	Anemia	Arm to carotid sinus	Lobeline	(3.5-8.0)	1
2	Anemia	Arm to lips	Fluorescein	12	2
3	Anemia	Arm to respiratory center	Theophylline-ethylene-diamine	9.2(6.0-15 9)	3
4	Anemia, hyperthyroidism	Arm to carotid sinus	Lobeline	12.8	4
5	Arteriosclerosis	Arm to conjunctiva	Fluorescein	25	5
6	Arteriosclerosis	Arm to foot	Fluorescein	(71-97)	5
7	Arteriosclerosis	Arm to hand	Fluorescein	(51-54)	5
8	Arteriosclerosis	Arm to lips	Fluorescein	29	5
9	Arteriosclerosis	Arm to tongue	Macasol	18 5	6
10	Arteriosclerosis	Arm to perineum	Macasol	30 0	6
11	Arteriosclerosis	Arm to hand	Macasol	29.5	6
12	Arteriosclerosis	Arm to foot	Macasol	42	6

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59. CIRCULATION TIME IN PATHOLOGIC CONDITIONS. MAN

Circulation time = time required for an indicator substance introduced into the blood stream to traverse a particular vascular circuit. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Condition	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)	(E)
1	Anemia	Arm to carotid sinus	Lobeline	(3.5-8.0)	1
2	Anemia	Arm to lips	Fluorescein	12	2
3	Anemia	Arm to respiratory center	Theophylline-ethylene-diamine	9.2(6.0-15.9)	3
4	Anemia, hyperthyroidism	Arm to carotid sinus	Lobeline	12.8	4
5	Arteriosclerosis	Arm to conjunctiva	Fluorescein	25	5
6	Arteriosclerosis	Arm to foot	Fluorescein	(71-97)	5
7	Arteriosclerosis	Arm to hand	Fluorescein	(51-54)	5
8	Arteriosclerosis	Arm to lips	Fluorescein	29	5
9	Arteriosclerosis	Arm to tongue	Macasol	16.5	6
10	Arteriosclerosis	Arm to perineum	Macasol	30.0	6
11	Arteriosclerosis	Arm to hand	Macasol	29.5	6
12	Arteriosclerosis	Arm to foot	Macasol	42	6

	Condition	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)	(E)
13	Asthma	Arm to tongue	Decholin	(10-15)	7
14	Bronchial asthma	Arm to lung	Ether	6.9(2-10)	8
15	Bronchial asthma	Arm to tongue	Decholin	13.3(7-17)	8
16	Cardiac asthma	Arm to lips	Fluorescein	(20-32)	2
17	Cardiac asthma	Arm to lung	Ether	16(5-40)	8
18	Cardiac asthma	Arm to tongue	Decholin	29.2(12-73)	8
	Cardiac disease				
19	Unspecified	Arm to arm	Evans' blue (T-1824)	33.4(22.7-46.1)	9
20	Unspecified	Arm to arm	Fluorescein	33.5(19.0-45.2)	10
21	Unspecified	Arm to arm	Riboflavin	37.5(29.0-55.2)	10
22	Uncompensated	Arm to carotid sinus	Lobeline	30.2	4
23	Uncompensated	Arm to respiratory center	Theophylline ethylene-diamine	28.5(18-39)	11
24	Pseudocompensated	Arm to arm	Evans' blue (T-1824)	32	12
25	Compensated	Arm to arm	Evans' blue (T-1824)	21	12
26	Compensated	Arm to carotid sinus	Cyanide	18.3(12-22)	13
27	Compensated	Arm to carotid sinus	Lobeline	10(7-18)	14
28	Compensated	Arm to carotid sinus	Lobeline	13.4	4
29	Compensated	Arm to carotid sinus	Lobeline	10.3(6.4-19.4)	15
30	Compensated	Arm to respiratory center	Theophylline ethylene-diamine	14.5(13-16)	11
31	Compensated	Arm to tongue	Thiamine HCl	(5-20)	16
32	Compensated	Arm to tongue	Magnesium sulfate	13.0(6.6-17.0)	17
33	Compensated	Lung to face	Amyl nitrite	(17-27)	18
34	Decompensated	Arm to carotid sinus	Cyanide	38.3(16-55)	13
35	Decompensated	Arm to carotid sinus	Lobeline	23.7(16-81)	15
36	Decompensated	Arm to conjunctiva	Fluorescein	(16-25)	19
37	Decompensated	Arm to ear	Methylene blue	(20-45)	20
38	Decompensated	Rectum to lung	Ether	(32-65)	21
39	Without decompensation	Arm to ear	Methylene blue	(9-15)	20
40	Untreated	Arm to respiratory center	Sodium succinate	25.1(21-32)	22
41	Treated	Arm to respiratory center	Sodium succinate	19.2(16.7-22.0)	22
42	Cardiac failure	Arm to ear	Evans' blue (T-1824)	22.1(13-32)	23
43	Cardiac failure	Arm to tongue	Magnesium sulfate	30.3(17.2-42.0)	17
44	Cardiac failure	Arm to tongue	Calcium gluconate	(20-40)	24
45	Cardiac failure	Arm to tongue	Saccharin	(19-34)	25
46	Cardiac failure (rest)	Arm to carotid sinus	Lobeline	9.4	26
47	Cardiac failure (rest)	Arm to lung	Ether	6.5	26
48	Cardiac failure (rest)	Arm to tongue	Decholin	11.5	26
49	Cardiac failure (rest)	Arm to tongue	Decholin	27.9(11-69)	27
50	Cardiac failure (exercise)	Arm to tongue	Decholin	20.6(8-39)	27
51	Cardiac failure, mild	Arm to tongue	Thiamine HCl	(8-25)	16
52	Cardiac failure, moderate	Arm to tongue	Thiamine HCl	(10-50)	16
53	Cardiac failure, moderate to severe	Arm to femoral artery	Sodium I^{131}	35.1(19-67)	28
54	Cardiac failure, severe	Arm to tongue	Thiamine HCl	(13-55)	16
55	Congestive cardiac failure	Arm to carotid sinus	Lobeline	19(7-46)	14
56	Congestive cardiac failure	Arm to medulla	Aminophyllin	(24-38)	29
57	Congestive cardiac failure	Arm to tongue	Calcium gluconate	(17.0-60.8)	30
58	Congestive cardiac failure	Arm to tongue	Decholin	(21-70)	30
59	Congestive cardiac failure	Arm to tongue	Decholin	25.4(18-40)	31
60	Congestive cardiac failure	Arm to tongue	Decholin	31(17-55)	32
61	Congestive cardiac failure	Arm to tongue	Fluorescein	32.8(21.2-78.2)	30
62	Congestive cardiac failure	Arm to tongue	Magnesium sulfate	(16.8-71.0)	30
63	Congestive cardiac failure (before hexamethonium)	Arm to tongue	Decholin	30(16-47)	33
64	Congestive cardiac failure (after hexamethonium)	Arm to tongue	Decholin	23(12-45)	33
65	Congestive cardiac failure, chronic	Arm to tongue	Decholin	35(22-48)	34
66	Congestive cardiac failure, chronic	Arm to lung	Ether	16(11-24)	34

59. CIRCULATION TIME IN PATHOLOGIC CONDITIONS. MAN (Continued)

	Condition	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)	(E)
	Cardiac disease (concluded)				
67	Congestive cardiac failure, untreated	Arm to tongue	Saccharin	36 5(18-62)	35
68	Congestive cardiac failure, treated	Arm to tongue	Saccharin	19.4(13-33)	35
69	Congestive cardiac failure	Pulmonary artery to brachial artery	Evans' blue (T-1824)	24.9(14.5-35.3)	36
70	Left cardiac failure	Arm to lung	Ether	(4.5-7.0)	37
71	Left cardiac failure	Arm to tongue	Saccharin	(13.0-60.5)	37
72	Left cardiac failure	Arm to respiratory center	Theophylline ethylene-diamine	21(15.8-35.0)	3
73	Right cardiac failure	Arm to respiratory center	Theophylline ethylene-diamine	21(13-58)	3
74	Cardiac infarction, healed (rest)	Arm to arm	Evans' blue (T-1824)	18.3(12.0-25.7)	38
75	Cardiac infarction, healed (exercise)	Arm to arm	Evans' blue (T-1824)	14.4(9.5-27.2)	38
76	Rheumatic carditis	Arm to respiratory center	Theophylline ethylene-diamine	10.4(7.6-17.0)	3
77	Left ventricle failure	Antecubital vein to brachial artery	Evans' blue (T-1824)	54.5(35-88)	39
78	Left ventricle recovery	Antecubital vein to brachial artery	Evans' blue (T-1824)	35.5(21-63)	39
79	Mitral stenosis, failing	Antecubital vein to brachial artery	Evans' blue (T-1824)	41.5(35-49)	39
80	Mitral stenosis (recovery)	Antecubital vein to brachial artery	Evans' blue (T-1824)	28.5(24-34)	39
81	Mitral stenosis (rest)	Arm to arm	Evans' blue (T-1824)	27.1(17-40)	40
82	Mitral stenosis (exercise)	Arm to arm	Evans' blue (T-1824)	28.2(16-40)	40
83	Mitral stenosis	Pulmonary artery to brachial artery	Evans' blue (T-1824)	24 6	36
84	Tricuspid insufficiency	Pulmonary artery to brachial artery	Evans' blue (T-1824)	16.3	36
85	Compensated valvular disease	Arm to respiratory center	Theophylline ethylene-diamine	12 4(6 2-16 4)	3
86	Mitral lesions	Arm to throat	Macasol	26 9	41
87	Aortic lesions	Arm to throat	Macasol	20.2	41
88	Mitral and aortic lesions	[illegible]	[illegible]	24.8	41
89	Septal defects, uncomplicated[1]	[illegible]	[illegible]	(10-13)	42
90	Tetralogy of Fallot[1]	[illegible]	[illegible]	(3.8-4.8)	42
91	Cardiovascular disease	[illegible]	[illegible]	12(8-46)	43
92	Cardiovascular disease	Arm to tongue	Decholin	23.3(15-70)	44
93	Cardiovascular disease	Arm to tongue	Intra-sul (sulfur and salts	20(12-59)	43
94	Cardiovascular disease	Arm to tongue	K^{42}	23(14-66)	44
95	Chronic pulmonary disease, untreated	Arm to tongue	Saccharin	21 6(12-60)	35
96	Chronic pulmonary disease, treated	Arm to tongue	Saccharin	11.4(10-14)	35
97	Cirrhosis of liver	Rectum to lung	Ether	(34-180)	19
98	Cirrhosis of liver (before surgery)	Rectum to lung	Ether	(26-42)	45
99	Cirrhosis of liver (after surgery)	Rectum to lung	Ether	(12-24)	45
100	Emphysema and silicosis	Arm to carotid sinus	Lobeline	14 5(7.8-29.5)	46
101	Fever	Arm to lips	Fluorescein	(9-13)	2
102	Hypertension, essential	[illegible]	[illegible]	11.5(6.0-26.8)	46
103	Hypertension	[illegible]	[illegible]	12.8(10-17)	3
104	Hypertension	Arm to tongue	Calcium gluconate	(8-16)	24
105	Hypertension	Arm to tongue	Macasol	14.4	6
106	Hypertension	Arm to perineum	Macasol	22	6
107	Hypertension	Arm to hand	Macasol	23	6
108	Hypertension	Arm to foot	Macasol	36.5	6
109	Hypertension and arteriosclerosis	Arm to throat	Macasol	19.4	41
110	Hyperthyroidism	Arm to ear	Methylene blue	(8-9)	20

/1/ In children.

	Condition	Circuit	Indicator	Registration Time sec	Reference
	(A)	(B)	(C)	(D)	(E)
111	Hyperthyroidism	Arm to lips	Fluorescein	10.2	2
112	Hyperthyroidism	Arm to medulla	Aminophyllin	(9-11)	29
113	Hyperthyroidism	Arm to tongue	Calcium gluconate	(7-11)	24
114	Hyperthyroidism	Arm to tongue	Macasol	10.4	6
115	Hyperthyroidism	Arm to perineum	Macasol	15	6
116	Hyperthyroidism	Arm to hand	Macasol	16.3	6
117	Hyperthyroidism	Arm to foot	Macasol	21.3	6
118	Hyperthyroidism	Lung to face	Amyl nitrite	(8-13)	18
119	Hypothyroidism	Arm to lips	Fluorescein	26	2
120	Lumbar sympathectomy (before)	Arm to foot	Fluorescein	23(9-48)	47
121	Lumbar sympathectomy (after)	Arm to foot	Fluorescein	9.8(5-16)	47
122	Lung diseases	Lung to face	Amyl nitrite	(15-27)	18
123	Obesity	Arm to carotid sinus	Fluorescein	7.5(5.2-9.4)	46
124	Occlusive arterial disease	Arm to arm	Fluorescein	17.1(11-30)	47
125	Occlusive arterial disease	Foot to foot	Fluorescein	38.8(19-87)	47
126	Osler's disease	Arm to carotid sinus	Lobeline	19.8(7-27)	48
127	Pneumoconiosis	Arm to carotid sinus	Lobeline	(6-9)	1
128	Polycythemia	Arm to respiratory center	Theophylline ethylene-diamine	18.3(17.6-19.0)	3
129	Thromboangiitis obliterans	Arm to foot	Fluorescein	(69-82)	5
130	Thromboangiitis obliterans	Arm to hand	Fluorescein	55	5
131	Thromboangiitis obliterans	Arm to lips	Fluorescein	24	5
132	Thromboangiitis obliterans	Arm to tongue	Macasol	14.5(10-19)	6
133	Thromboangiitis obliterans	Arm to perineum	Macasol	22.35(10-39)	6
134	Thromboangiitis obliterans	Arm to hand	Macasol	24.5(15-39)	6
135	Thromboangiitis obliterans	Arm to foot	Macasol	38(20-74)	6
136	Thrombophlebitis migrans	Arm to arm	Fluorescein	15.5(13-18)	47
137	Thrombophlebitis migrans	Arm to foot	Fluorescein	32.6(24-41)	47
138	Thyrotoxicosis, untreated	Arm to respiratory center	Theophylline ethylene-diamine	7.1(5.6-13.6)	3
139	Thyrotoxicosis, treated	Arm to respiratory center	Theophylline ethylene-diamine	14(10.0-17.4)	3
140	Varicose veins[2]	Foot to tongue	Calcium gluconate	540	49

/2/ Measured while standing.

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60. CEREBRAL BLOOD FLOW: MAN, MONKEY

Subjects recumbent, lines 1-8 Method N_2O = nitrous oxide, *intermittent sampling* (Kety); Kr^{85} = radioactive krypton, intermittent sampling (Lassen and Munck), I-B = intercalated bubble flow meter. *Values determined in vivo* Vascular resistance = $\frac{\text{mean arterial pressure}}{\text{blood flow}}$. Cerebral arterio-venous O_2 difference (the quantity of O_2 removed by the brain from each 100 ml of blood flowing through the brain) = $100 \times \frac{\text{column F}}{\text{column E}}$. Values in parentheses are ranges, estimate "c" (cf Introduction).

	Condition	Sex	Age yr	Method	Blood Flow ml/100 g/min	O_2 Consumption ml/100 g/min	Vascular Resistance mm Hg/ml/100 g/min	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Man							
1	Normal, alert[1]	♂	25	N_2O	54(40-67)	3.3(2.6-4 2)	1.6(1.2-2.5)	1-3
2	Normal, alert	♂, ♀	29	N_2O	52(40-64)	3.1(2.2-3 9)	1.8	4
3			56	N_2O	46(30-64)	2.9(2.0-3.9)	2.2	
4		10♂, 10♀	38(17-55)	Kr^{85}	52(33-67)	3 4(2 4-4 5)	1.8(1.1-2.3)	5
5	Passive hyperventilation with air	♂	26(23-31)	N_2O	41(36-47)	4.7(4.0-5.1)	2.4(1.7-3.5)	1
6	Inhaling 5-7% CO_2	♂	25	N_2O	93(65-141)	3 3(2.4-3.9)	1.1(0.7-1.4)	3
7	Inhaling 85-100% O_2	♂	25	N_2O	45(34-55)	3.2(2.6-4.4)	2.2(1.8-2.7)	
8	Inhaling 10% O_2	♂	25	N_2O	73(54-93)	3.2(2.6-3.5)	1.1(0.8-1.6)	
9	Cerebral arteriosclerosis			N_2O	41(31-56)	2.8(1.7-3 6)	3 0(1.9-3.5)	6
10	Anesthetized (thiopental)			N_2O	60(33-117)	2.1(1.5-3.0)	1.3(0.6-2.1)	7
	Monkey							
11	Anesthetized[2] (light barbiturate)			I-B	47(33-74)	3.7(2.5-4.5)		8
12	Anesthetized (thiopental)			I-B	24(14-46)	2 2(0.9-3.8)		

(1) Approximately same values found in subjects with essential hypertension [9] and with schizophrenia [10].
(2) Active reflexes, spontaneous movements

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61. RENAL BLOOD FLOW. MAMMALS

Abbreviations PAH = p-aminohippurate plasma clearance, UV/P = diodrast plasma clearance.

Part I MAN

Effective plasma flow determined from p-aminohippurate, or diodrast, plasma clearance. Effective blood flow calculated from effective plasma flow divided by 1 minus hematocrit (EBF = $\frac{EPF}{1 - hematocrit}$). Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Subjects: Age	Subjects: No. and Sex	No. of Observations	Method	Plasma Flow ml/min/1.73 sq m body surface area	Blood Flow ml/min/1.73 sq m body surface area	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	2-40	91♂	258	PAH, UV/P	655(492-818)[b]	1166(910-1422)[b]	1
2	2-40	31♀	91	PAH, UV/P	600(498-702)[b]	940(756-1124)[b]	
3	29-29	10♂	27	UV/P	786(529-993)	1339(860-1780)	2
4	30-39	10♂	21	UV/P	676(323-956)	1145(521-1622)	
5	40-49	9♂	14	UV/P	689(509-846)	1150(868-1342)	
6	50-59	7♂	21	UV/P	586(343-804)	987(746-1341)	
7	60-69	2♂	5	UV/P	584(498-680)	997(844-1192)	
8	22-51	11♀	16	UV/P	596(441-782)	973(718-1264)	
9	23-57	2♂, 11♀	13	PAH	497(361-648)	881(631-1179)	3
10	20-29	9♂	9	UV/P	614(481-724)	1077(859-1353)	4
11	30-39	9♂	9	UV/P	649(519-804)	1181(931-1493)	
12	40-49	10♂	10	UV/P	574(396-736)	1008(737-1252)	
13	50-59	11♂	11	UV/P	500(341-617)	849(631-1007)	
14	60-69	10♂	10	UV/P	442(253-534)	775(453-941)	
15	70-79	9♂	9	UV/P	354(234-519)	589(411-845)	
16	80-89	12♂	12	UV/P	289(147-462)	475(237-732)	

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61. RENAL BLOOD FLOW: MAMMALS (Concluded)

Part II. DOG, RABBIT, RAT

	Animal	No. of Subjects	Condition	Method	Plasma or Blood	Flow: ml/min (both kidneys)	Flow: ml/min/g kidney weight	Flow: ml/min/kg body weight	Flow: ml/min/sq m body surface area	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Dog	6	Unanesthetized	Calculated	Plasma	212[1]	2.20[2]	15.8		1,2
2				Thermostromuhr	Blood	384	4.00	28.6		
3		51	Unanesthetized	Calculated	Plasma	158[1]	1.73[2]	11.5		3-6
4				Direct venous outflow	Blood	288	3.15	21.0		
5		75	Unanesthetized	PAH, UV/P	Plasma	166	1.90[2]	13.5	266	7
6				Calculated	Blood	302[1]	3.46	24.6	484	
7		11	Unanesthetized	Calculated	Plasma	156[1]	2.20[3]	10.0	248	8
8				Urea extraction	Blood	284	4.00	18.0	450	
9		77	Unanesthetized	Calculated	Plasma			9.9[1]	250	9
10				Phenol red extraction	Blood			18.0	460	
11		13	Pentobarbital anesthesia	Calculated	Plasma	212[1]	2.42	16.4		8
12				Direct venous outflow	Blood	376	4.30	29.2		
13		13	Pentobarbital anesthesia	Calculated	Plasma		1.76[1]			10
14				Rotameter: arterial inflow	Blood		3.20			
15		22	Pentobarbital anesthesia	Calculated	Plasma	130[1]	1.54	9.6		11
16				Rotameter: venous outflow	Blood	236	2.80	17.6		
17		10	Chloralose anesthesia	Calculated	Plasma	197[1]	1.82[2]	12.8		12
18				Bubble meter: arterial inflow	Blood	358	3.30	23.4		
19	Rabbit	37	Unanesthetized	PAH, UV/P	Plasma	45	2.40[4]	15.4[5]	240	13-15
20				Thermostromuhr	Blood	82	4.30	27.6	438	
21	Rat	100	Unanesthetized	PAH, UV/P	Plasma	4.6	3.60[4]	27.7	163	16-20
22				Calculated	Blood	8.4[1]	7.34	51.0	296	

/1/ Calculated for an average hematocrit ratio of 0.45. /2/ Kidney weight in grams = 7.1 x body weight in kilograms. /3/ Kidney weight in grams = 96.2 x sq m body surface area. /4/ Kidney weight in grams = 8.0 x body weight in kilograms. /5/ Calculated for an average body weight of 2.9 kilograms.

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62. HEPATIC BLOOD FLOW: MAMMALS

Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I: MAN

	Condition	Method	Blood Flow ml/min/sq m body surface area	Blood Flow ml/min/subject	Reference
	(A)	(B)	(C)	(D)	(E)
1	Normal	Bromsulphalein	833(600-1200)		1,2
2			836(500-1290)		3
3			865(640-1070)		4
4			883(744-1085)		5
5			895(756-1098)	(1192-1737)	6
6			1530(970-2720)[1]		3
7			798		7
8			(1390-2500)		8
9		Bromsulphalein minus const. inf.[2]		676(503-1055)	9
10		Bromsulphalein, urea excretion	851(641-1210)		10
11		Urea excretion	800(600-1160)		1,2
12		Colloidal gold, Au^{198}		1425(1120-2010)	11
13		Colloidal gold		731(533-1668)	12
14			597(357-951)	1090(542-1779)	13
15		Galactose clearance	806	1460	14
16		P^{32} labelled $CrPO_4$		(1500-1800)	15
17	Pregnant	Bromsulphalein	898(621-1425)	(1092-2065)	6
18	Preanesthetization	Bromsulphalein		1258(746-2140)	16
19	Anesthetized	Bromsulphalein		884(467-1850)	16
20	Anesthetized, low spinal	Bromsulphalein	742(510-1161)		5
21	Anesthetized, high spinal	Bromsulphalein	590(295-919)		5
22	Cirrhosis	Colloidal gold, Au^{198}		525(315-775)	11
23		Colloidal gold		437(96-1054)	12
24			212		13
25		Galactose clearance		(490-1660)	14
26	Cirrhosis, Laennec's	Bromsulphalein		695(470-710)	2
27	Hepatitis	Colloidal gold	266		13
28		Galactose clearance		(1920-2557)	14

/1/ Peripheral venous bromsulphalein less than 1 mg/100 ml. /2/ Bromsulphalein minus constant infusion rate, 2.5 mg/min/sq m.

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Part II: CAT, DOG, RAT

	Animal	Condition	Method	Blood Flow ml/min/animal	Blood Flow ml/min/kg body wt	Blood Flow ml/min/100 g liver	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	C	[illegible]	[illegible]			(33-48)	1
2	D	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4		[illegible]	[illegible] measured	[illegible]	[illegible]	[illegible]	[illegible]
5			Bromsulphalein; plasma dye clearance	146(72-272)	48.6(37.7-65.4)		4
6		Anesthetized	Blood collected and measured	390(250-534)	44(26-85)	95(64-144)	5
7			Bromsulphalein		35(20-50)		6
8			Bromsulphalein	690(252-1878)	42(16-111)	140(57-358)	7
9			Bromsulphalein	(403-1304)			8
10			Stromuhr (hepatic artery)	143(101.3-187.0)	7.8(5.0-11.8)		9,10
11			Stromuhr (portal vein)	268(123.5-565.0)	31.7(8.2-33.2)	64	9,10
12			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15			[illegible] (hepatic artery)	[illegible]	[illegible]	[illegible]	[illegible]
16			Thermostromuhr (hepatic artery)	144(43-430)	7.5(2-16)	25(11-44)	14
17			Thermostromuhr (portal vein)	150(80-200)			13
18			Thermostromuhr (portal vein)	147(52-400)	15.5(5-37)		14
19		Anesthetized, pre-Eck fistula	Bromsulphalein	(403-922)			8
20		Anesthetized, Eck fistula	Bromsulphalein	(202-439)			8
21		Basal, 3-da post-operative	Bromsulphalein		42.5		15
22			Thermostromuhr	330(157-520)	26(18-33)	58.5(43-70)	16,17
23			Urea excretion	383(241-705)	32(18-48)		18
24	Rat	Unanesthetized	Thermoelectric			79(75-92)	19
25		Anesthetized	Thermoelectric			42	19

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63. DYNAMICS OF PULMONARY CIRCULATION: MAN, DOG

Pulmonary pressure zero point = 10 cm anterior to back in man; zero point = back in dog

	Condition	No. of Observations	Pressure, mm Hg				Blood Flow L/min	Vascular Resistance dynes sec/cm[5]	Reference
			Arterial			Capillary Mean			
			Systolic	Diastolic	Mean				
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Man								
1	Resting	3[1]	25	14	18		6.0	176[2]	1
2		8[1]			14		7.1	158[2]	2
3		10[1]	25	11	16		5.4	238[2]	3
4		8	23	9	15	9	7.4	67	4
5		9			16	7	5.5	131	5
6	Exercise, supine	8[1]			15		10.4	115[2]	2
7		7			21	10	9.6	90	6
8	Exercise, standing	3[1]	26	9	16		12.0	76[2]	1
9	Hypoxia	9			20	7	5.5	189	5
10		8[1]	26	12	18	8	8.0	119	7
11	Saline infusion	4[1]			23	16	6.7	84	8
	Drug effect (IV injection)								
12	Epinephrine	5[1]			19	7	7.9	121	9
13	Norepinephrine	9	28	11	21	15	4.5	118	10
14	Tetraethylammonium chloride	3			15	10	4.7	85	11
	Pathologic								
15	Emphysema, mild	6[1]	29	12	18		5.5	262[2]	12
16	Emphysema, severe	6[1]	43	16	28		5.6	400[2]	12
17	Cor pulmonale, with hypoxia	11[1]	43	19	28		5.4	414[2]	12
18		17			35	9	5.4	440	13
19	Cor pulmonale, with congestive failure	4[1]	74	39	52		7.4	562[2]	12
20	Primary pulmonary hypertension	3[1]	101	47	66		2.9	1776[2]	14
21	Left ventricular failure	10			45	30	3.5	344	4
22	Mitral stenosis	21			61	29	4.3	491	15
23		22	68	33	47	28	4.0	448	16
24	Mitral insufficiency	1			15	12	5.9	41	17
25	Mitral stenosis and insufficiency	12			36	23	3.8	304	17
26	Aortic stenosis and insufficiency	6			29	16	5.0	208	18
27	Chronic constrictive pericarditis	4	36	22	26	20	4.3	112	19
	Atrial septal defect								
28	Left to right shunts	3[1]	38	12	23	13[3]	16.5	49	20
29		7[1]	31	14	21	8	18.0	58	4
30	Right to left shunts	1[1]	96	53	68	9[3]	2.6	1770	20
31		2[1]	88	59	73		3.5	3710[2]	21
32	Patent ductus arteriosus	6	43	19	29		12.2	190[2]	22
33		2	34	17	28	14	19.0	53	4
34		3[1]	46	23	31		7.7	300[2]	23
35		13[1]			36		12.4	200[2]	24
36	Tetralogy of Fallot	1		8	4	6	2.5	192[2]	25
37	Pulmonary stenosis	8	24	10	17	11	5.4	89	a
38	Eisenmenger syndrome	3	120	65	87	8	3.3	1915	4
39		4			86		3.5	2225[2]	a
40	Ventricular septal defect	15[1]			37		10.3	248[2]	24
41		2	35	20	27		5.7	380[2]	a
	Dog								
42	Resting (anesthetized)	36			18	10	2.3	285	26
43	Resting	16			17	4	3.2	325	27
44	Hypoxia, moderate (anesthetized)	13			22	8[3]	2.4	467	26
45	Hypoxia, moderate	16			26	4[3]	3.8	463	27
46	Hypoxia, severe	3			26	9[3]	8.1	167	26

/1/ Pressure zero point corrected to approximately 10 cm. /2/ Total pulmonary resistance, utilizing pulmonary arterial mean minus pulmonary "capillary" mean as pressure gradient /3/ Pulmonary venous or left atrial mean pressure

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64. LIMB BLOOD FLOW: MAN

Part I: EFFECT OF TEMPERATURE

Abbreviations: A = air plethysmography; W = water plethysmography; S = Stewart dye-dilution (Evans' blue dye injected at constant rate into brachial artery; dye concentration determined in continuously sampled venous blood). Values in parentheses are ranges. (cf. Introduction).

	Extremity	Condition of Blood Vessels	Temperature °C Ambient	Temperature °C Bath	Blood Flow Method	Blood Flow ml/min/100 ml segment	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Forearm	Normal		32	W	1.8(1.5-2.5)[c]	1
2			25	32	W	1.8(0.4-3.2)[b]	2
3			15-20	32	W	2.3(1.2-3.0)[c]	3,4
4			22-25	32	W	2.6(1.6-4.8)[c]	5
5			15-20	33	W	2.7(1.9-3.8)[c]	3,4
6			15-20	35	W	4.2(1.5-7.0)[a]	3,4
7			18.5		A	3.1(2.6-3.6)[b]	4
8			25-27		S	4.5(2.8-6.3)[c]	6
9			27-29		A	4.9(1.7-7.3)[c]	7
10			22-25	28-30	W	1.6(1.0-2.5)[c]	8
11		Maximal constriction		10-14	W	0.7(0.5-1.0)[c]	9
12			22-25	17	W	0.7(0.5-1.0)[c]	5
13		Maximal dilatation		45	W	17.6(11.0-25.4)[c]	3
14			22-25	45	W	7.6(3.7-12.7)[c]	5
15	Hand	Normal	21	32	W	3.5(1.2-5.3)[c]	10
16			25	32	W	9.3(5.1-13.5)[b]	2
17			24	35	W	5.9(2.7-9.6)[c]	11
18			21-24		A	2.1(0.5-6.4)[c]	12
19			25-29		A	9.3(5.8-16.5)[c]	12
20		Maximal constriction		10-14	W	2.5(0.3-4.7)[c]	9
21		Maximal dilatation		45	W	22.0	9
22	Finger	Normal	"Comfortable"		A	(15-40)[d]	13
23		Maximal constriction				0.2	14
24		Maximal dilatation		45	W	90.0	13
25	Leg	Normal		32	W	1.4(0.8-2.6)[c]	9
26		Maximal constriction		10-14	W	1.2(0.4-1.5)[c]	9
27		Maximal dilatation		45	W	3.6	15
28	Calf	Normal	25	32	W	1.4(0.4-2.4)[b]	2
29	Foot	Normal	21	32	W	2.0(0.5-4.4)[c]	10
30			24-26.5	32	W	3.9(1.4-7.8)[c]	16
31				32	W	2.1(1.2-2.8)[c]	15, 17
32		Maximal dilatation		45	W	18.1(11.0-34.0)[c]	16

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64. LIMB BLOOD FLOW: MAN (Concluded)

Part II: EFFECT OF VARIOUS CONDITIONS

Ambient temperature = 21-23°C. (+) = increase in blood flow, (-) = decrease in blood flow.

	Condition	Blood Flow ml/min/100 ml segment					Reference
		Forearm	Hand	Digit	Foot	Calf	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Anemia	2 5	6.3	12	2.0	2.8	B, C, 1; D-F, 2
2	Aortic insufficiency	2 0	6.7			1.7	3
3	Arteriosclerosis			3	2.1	1.6	2
4	Hypertension	2.9	5 4			2.4	4
5	Hyperthyroidism	4 4	11 6	30	4 5	3 0[1]	B, C, 5, D-F, 2
6	Mitral stenosis	1.7	6.5				3
7	Raynaud's phenomenon		2.5	1	2.0	1.8	2
8	Schizophrenia	2.3	7.2			1.6	6
9	Sympathectomy, 1-2 da		35.0	100	22 0	7.5	7
10	1-2 wk		11 0	40	8.0	4 4	
11	>3 mo		8.0	28	4.5	3.3	
12	Varicosities					2.4	8
13	Anesthesia, general		20 0	80	15.0	7.8	9
14	Low spinal		2.0	6[2], 70[3]	12 0	6.0	10, 11
15	High spinal		+	60[2], 100[3]	+	+	10, 11
16	Epinephrine		1.8	-	-	4 0	12
17	Tolazoline HCl		28.0	80	17.0	3.6	13
18	Reflex heating		30.0	90	18.0	4 5	2
19	Exercise, before	1.5				2.5	B, 14, F, 15
20	Maximum during	4				30	
21	Immediately after	22				77	

/1/ 8 1 also reported (16). /2/ Finger. /3/ Toe.

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Condition[illegible] (N_2) = norepinephrine infused at rate of 0.018(0.001-0.035) mg/[illegible] n at room temperature of 26-29°C; V = after vasodilatation by indirect heating for 1/2 hou[illegible] pplemented by autonomic ganglion blockade; V + AI = V + A administered via an intravenous drip (5% glucose in water); H = after indirect heating for 1 hour or more, supplemented by autonomic ganglion blockade; S = after spinal anesthesia; T = 3-5 years after thoracolumbar sympathectomy; B = after intravenous benzodioxane. Values in parentheses are *ranges*, *estimate "b"* (cf. Introduction).

	Condition	Procedure	Blood Flow[1] ml/min/sq cm skin	Arterial Blood Pressure Systolic[2] mm Hg	Arterial Blood Pressure Diastolic[3] mm Hg	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
			Finger			
1	Normal	RT	0.20(0.08-0.32)	104(70-138)	65(39-91)	1,2
2		V	0.28(0.22-0.34)	101(81-121)	58(35-81)	3-6
3		V + A	0.29(0.21-0.37)	87(67-107)	52(32-72)	1
4		V + AI	0.26(0.16-0.36)	91(62-120)	58(40-76)	7,8
5	Normal (N_2)	V + AI	0.24(0.12-0.36)	134(100-168)	83(57-109)	7,8
6	*Pregnancy, 3rd trimester*	*RT*	*0.29(0.15-0.43)*	*106(83-129)*	*68(48-88)*	9
7		V + A	0.33(0.19-0.47)	91(64-118)	58(32-84)	
8	Primary hypertension	RT	0.18(0.02-0.34)	168(113-223)	103(55-151)	1
9		V + A	0.31(0.21-0.41)	120(74-166)	75(38-112)	
10		V + AI	0.21(0.01-0.41)	122(74-170)	27(41-113)	7
11	Primary hypertension (N_2)	V + AI	0.16(0.00-0.38)	184(133-235)	105(65-145)	7
12	*Hypertension of pregnancy,*	*RT*	*0.29(0.17-0.41)*	*121(90-152)*	*73(58-88)*	9
13	3rd trimester	V + A	0.35(0.23-0.47)	96(56-136)	62(33-91)	
14	Cushing's syndrome[4]	V + AI	0.31(0.17-0.45)	100(67-133)	62(28-92)	8
15	Cushing's syndrome[4] (N_2)	V + AI	0.27(0.10-0.44)	151(96-206)	94(60-128)	8
16	Clubbing	V	0.35(0.24-0.46)	109(72-135)	72(59-85)	3,5
17	Coarctation of aorta	V + A	0.33	111	64	3
18	*Scleroderma*	*V + A*	*0.14(0.00-0.36)*			
19	Raynaud's disease	V + A	0.23(0.05-0.41)			
20	Acrocyanosis	V + A	0.33			
21	Lymphedema	V + A	0.35(0.26-0.44)			
22	Coronary occlusion	V	0.22(0.09-0.35)			
			Great Toe			
23	*Normal*	*H*	*0.21(0.15-0.29)*	*87(57-117)*		3
24		S	0.13(0.05-0.21)			
25	Primary hypertension	H	0.21(0.08-0.34)			
26		T	0.11(0.00-0.23)			
27		H, T	0.16(0.05-0.26)			
28		H, T, B	0.16(0.04-0.27)			
29	Diabetes *mellitus*[5]	*H*	*0.17(0.05-0.28)*			
30	Thromboangiitis obliterans	H	0.10(0.01-0.23)			
31	Coarctation of aorta	H	0.24	75		
32	Cold injury	H	0.14(0.05-0.24)	84		
33	Scleroderma	H	0.12			
34	Raynaud's disease	H	0.12(0.01-0.23)			
35	Arteriosclerosis	H	0.08			
36	Thrombophlebitis	H	0.17	91		

/1/ Determined calorimetrically on the terminal phalangeal skin of 3rd or 4th finger, or on the terminal phalangeal skin of the great toe. /2/ Determined with a Gaertner capsule by the "flushing" technique on the great toe or middle phalanx of the 3rd or 4th finger. /3/ Determined from the point of cessation of throbbing on the middle phalanx of the 3rd or 4th finger. /4/ Caused by endogenous secretion of excessive adrenal corticosteroids, or by their exogenous administration. /5/ Of less than ten years' *duration and without overt arterial disease.*

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66. RESISTANCE OF ANIMAL TISSUE TO ARRESTED CIRCULATION: MAMMALS

Circulation arrested by obstructing or bypassing total afferent blood supply to organ. Adult tissue, in situ, at normal body temperature, unless otherwise indicated.

	Tissue	Animal	Initial Disappearance of Function[1]		Development of Irreversible Changes[2]		Reference
			min	Remarks	min	Remarks	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Brain, cerebral cortex	Cat	1/6-1/4		<3		C,1,2,E,3
					>5-10		4
2					1-8	Newborn animal	5,6
3		Dog			12-20		
4	Brain stem						
5	Pupillary centers	Dog	3-4	Isolated, perfused head			7
6	Cardioregulatory, vasomotor, and adrenosecretory centers	Dog	4-5	Isolated, perfused head	15-30	Isolated, perfused head	7
7					5-10		8
8	Respiratory center	Dog, rat	4-5	Isolated, perfused head	15-30		7
9			1/3-1/2				6,9
10		Rat	20-40	Newborn animal, decapitated			9
11	Spinal cord	Cat	2/3-1		35-45		C,10,E,11
12					90-120		12
13		Rabbit	2/3-2				13
14	Heart	Dog, rabbit, rat	5-20				14
15	Lung	Dog			30-45	Criterion: death of animal	15
16	Kidney	Dog			30-60		16,17
17					>120		18,19
18		Rabbit			60-90		20
19		Rat			<120		19,21
20	Liver	Dog			20-75		22-25
21					>60[3]		24
22	Skeletal muscle	Dog, rabbit, rat	120-360		480		26,27
23	Small intestine	Dog			120-240+	Criteria electrical reaction and death of animal	28
24	Testis	Rat			10-30	Histological study of spermatogenesis	29

/1/ Interval from the start of circulatory arrest to the disappearance of a specific functional activity; i.e., the time of survival of a function, without implication of reversibility. /2/ Interval from the start of circulatory arrest to the occurrence of irreversible changes in the organ so that the function does not reappear, i.e., the time of survival of an organ before irreversible changes occur /3/ Value for liver at 24-27°C.

Contributors (a) Sonnenschein, Ralph R., Robert Lewis, and Louise Darling, (b) Van Harreveld, A., (c) Wesolowski, Sigmund A

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For a comprehensive review of the subject, see reference 22. Lymph collections made during period of anesthesia, unless otherwise specified. Condition: *F* = fasting, *NF* = non-fasting. Anesthetic: B = barbiturate, C = chloroform, E = ether, *I* = inhalation anesthetic, L = *chloralose*, *M* = *morphine*, U = urethane, X = *unspecified*. *Values in parentheses are ranges, estimate "c" (cf. Introduction).*

	Animal	Subjects No.	Subjects Condition	Weight kg	Anesthetic	Lymph Flow ml/hr	Lymphocytes (cells/cu mm) x 10^3	Lymphocytes (cells/hr/kg) x 10^6	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
					Thoracic Duct				
1	Man	5	NF	60.6(48 5-78.5)	X[1]	48(37-83)	11.4(2.1-25.5)	8.7	1
2		1	Fistula	50	X[1]	(53-78)	1.8	3.1	2
3	Calf	4	NF	34.4(29-38)	B, I	115(51-172)	26.1(21.5-30.6)	85(43-117)	3
4	Cat	21	NF[2]	1.9	B, U	5.0(1.8-7.3)	14.2(4.3-29.6)	35.5(9.6-92 6)	4
5	Dog	78	NF	10.4(6.3-15.7)	C, E, M	23.6(7.0-68.1)			5
6		21	F[3]	10	L			*21.2(3.0-87.5)*	6
7		10	F[4]	10.9(5.4-20.8)	M	8.6(4.0-11.6)	7.2(3-20)	5.7	7
8	Goat	4	NF	*32(25-35)*	*B, I*	*102(30-154)*	*6.9(2.7-9.0)*	*23.0(6.3-55.7)*	3
9	Guinea pig	40	NF	0.303	B	0.95	14.8	45.7	8
10	Monkey	26	NF	3.5	B	3 0(0.95-8.1)	29.9(2.9-100.3)	26.7(2.8-71.2)	9
11	Mouse	7	NF	0.023	B	0.08		69	10
12	Rabbit	9	NF	2.5(2.1-3.2)	B, E	4.6(1.5-9.0)	36.1	69(19-126)	11
13		7	NF	2.5	B	4.0	32.3	54.5	12
14	Rat	28	NF	0.25(0.20-0.29)	B	0.88(0.5-1.2)	31.5	107(60-181)	13
					Intestinal Lacteal Lymphatics				
15	Mouse	5	NF	0.03	B	0.10	47.1	133.7	10
16	Rat	8	*NF*[5]	*(0.18-0.24)*	X[1]		*34.6(18.3-60.5)*		14
					Abdominal Thoracic Duct				
17	Mouse	20	NF	0.02	B	0.1	11.7	57.0	15
18	Rat	7	NF	(0.16-0.18)	B[1]			246	16
19		5	NF	(0.36-0.40)	B[1]			158	16
20		9	NF	0.155(0.135-0.170)	E[1]	0.66(0.39-1.04)	32.5(13.2-61.1)	133(45-212)	17
21		9	NF	0.274(0.21-0.31)	E[1]	1.06(0.81-1.28)	32.1(15.4-55.9)	121(74-198)	17
22		27	NF[6]	0.172(0.145-0.200)	X[1]	1.6(0.7-2.7)	20.0	185	18
23		8	NF[6]	0.199(0.16-0.29)	B, E[1]	*5.8(2.1-8.2)*	*3.3(2.2-6.2)*	95.6	19
24		6	NF[7]	0.235(0.20-0.26)	B, E[1]	*0.61(0.53-0 66)*	11.8(7.2-13.1)	34.5	19
					Cervical Lymphatics				
25	Guinea pig	5	NF	0.235	-B	0.046	6.5	1.36	8
26	Rabbit	1	NF	2.05	B	0.16	37.2	3.2	9
27	Rat	10	NF	0.25	B	0.038	7.1(1.5-17.5)	1.24	*20*
					Right Duct				
28	Monkey	1	NF	3.8	B	0.17	10.2	0.45	9
29	Monkey[8]	5	NF	2.49	B	*2.07(1.1-3.6)*	40.4(32.0-56.4)	42.3(10.8-111.0)	9
30	Rabbit	3	NF		B	*0.35(0.24-0.46)*	40.9(39.5-43.6)		12
31	Rat	10	NF	*0.303(0.280-0 334)*	B	0.1(0 07-0.14)	17.3(13.0-23.7)	5.7	21
					Subclavian Duct				
32	Monkey	4	NF	2.6	B	0.06(0.04-0.06)	4 2(2.5-7.0)	0 08(0 06-0.10)	9
33	Rabbit	7	NF[9]	2.3	B[1]	0.69	38 9(13.8-50 8)	*11.2*	12
34		5	NF[10]	2.3	B[1]	1 33	22 5(19.3-26.4)	*14.2*	12

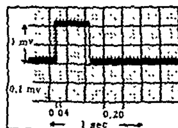
/1/ Lymph collected after recovery from anesthetized state. /2/ Fed cream 4 hours *before*. /3/ 36-48 hours. /4/ 24-36 hours. /5/ Oral 0.2% saline. /6/ Oral saline. /7/ Oral water. /8/ Right duct functional thoracic duct. /9/ Prone. /10/ Sitting.

Contributor: Reinhardt, William O.

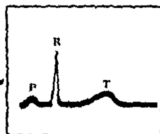
References [1] Bierman, H. R., R L. Byron, K. H. Kelly, R. S Gilfillan, L. P. White, N. E. Freeman, and N. L. Petrakis. 1953. J Clin. Invest. 32 637. [2] Courtice, F. C., W. J. Simmonds, and A W. Steinbeck. *1951. Austral.* J. Exp. Biol. 29.201. [3] Wingvist, G. 1954. Acta anat , Suppl., Basel 22 21. [4] Adams, W. S., *R. H. Saunders*, and J. S. Lawrence. 1945. Am J. Physiol. 144 297. [5] Heidenhain, R. 1891. Arch *ges Physiol.* 49 209. [6] Yoffey, J. M. 1935-36. J. Anat., Lond. 70:507. [7] Chistoni, A. *1909. Arch fisiol., Fir* 6:74. [8] Reinhardt, W. O , and J. M. Yoffey. 1956. Am. J. Physiol. 187·493 *[9] Reinhardt, W. O. Unpublished. [10] Shrewsbury, M. M. Unpublished.* [11] Sanders, A. G., *H. W. Florey, and J. M. Barnes.* 1940. Brit J. Exp. Path. 21:254. [12] Hughes, R., A. J. May, and *J. G. Widdicombe. 1956. J.* Physiol., Lond. 132:384. [13] Hungerford, G. F., W. O Reinhardt, and C. H. *Li. 1952 Blood*, N. Y. 7:193. [14] Mann, J. D., and G. M. Higgins. 1950. Ibid. 5:177. *[15] Shrewsbury,* M. M. 1958. Proc. Soc. Exp Biol., N. Y. 99.53. *[16] Whaler, B. C., and J. G. Widdicombe 1946. J.* Physiol., Lond. 132.41. [17] Hungerford, G. F., and W O. Reinhardt. 1950. Am. J. *Physiol.* 160 9. [18] Gowans, J. L. 1957. Brit. J. Exp. Path. 38.67. [19] Shrewsbury, M M., and W. *O. Reinhardt.* 1952. Am. J Physiol. 168.366 [20] Reinhardt, W. O., and C. H Li *1945. Proc. Soc. Exp.* Biol., N. Y 58.321. [21] Schooley, J. 1958. Ibid. 99·511. *[22] Yoffey, J. M., and F. C. Courtice 1956.* Lymphatics, lymph and lymphoid tissue. Edward Arnold, Lond.

Part I: STANDARD LIMB LEADS

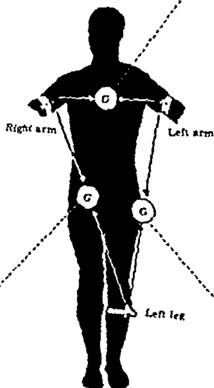
... and 5 mm squares. *Standardization of the electro-* ... a vertical deflection of ... contal axis represents an ... in potential between ... des on the *right arm* and ... diographic galvanometer.

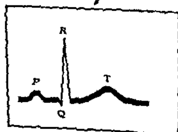


Standardization

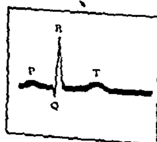


Lead I





Lead II



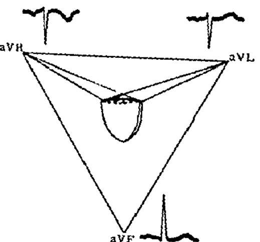
Lead III

Reference Rushmer, R. F. 1955. Cardiac diagnosis. W. B. Saunders, Philadelphia. p 237.

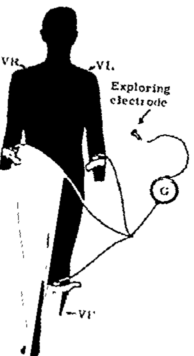
68. ELECTROCARDIOGRAPHIC LEADS IN STANDARD USE. MAN (Concluded)

Part II UNIPOLAR LIMB LEADS

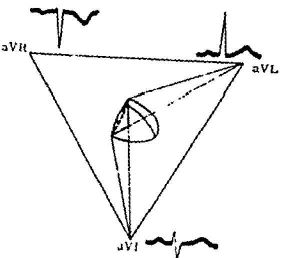
When the heart is oriented vertically, the QRS complexes are similar in leads aVR and aVL. In the horizontal heart, aVR and aVL are essentially mirror images, a phenomenon which suggests that the wave of excitation actually progresses from right to left. This is confirmed by the diphasic QRS in lead aVF.



Vertical heart



G = galvanometer

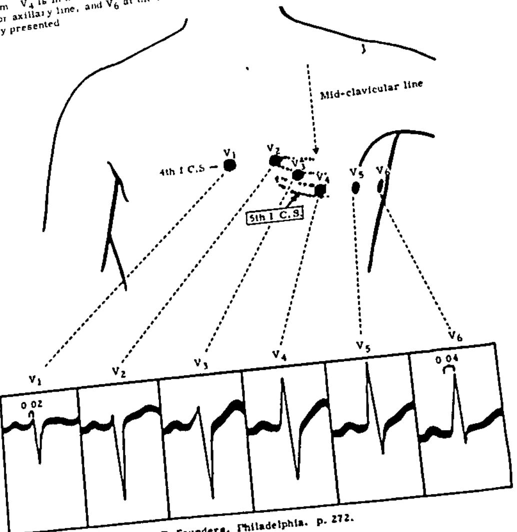


Horizontal heart

Reference Rushmer, R F. 1955 Cardiac diagnosis. W. B. Saunders, Philadelphia pp. 262, 274.

Part III UNIPOLAR PRECORDIAL LEADS

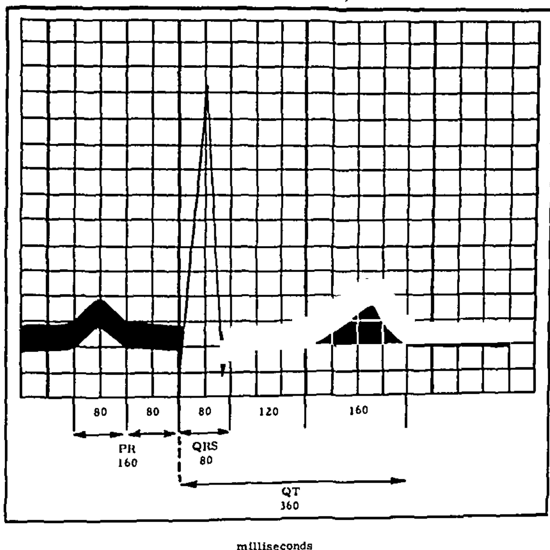
Unipolar precordial electrodes are routinely placed on six positions. V_1 is in the fourth I.C.S. (intercostal space) at the right sternal edge. V_2 is in the fourth I.C.S. just to left of the sternum. V_4 is in the fifth I.C.S. in the mid-clavicular line, with V_3 midway between V_2 and V_4. On a horizontal line drawn from V_4, V_5 is located at the anterior axillary line, and V_6 at the mid-axillary line. Electrocardiographic patterns recorded from the six precordial electrode positions are schematically presented.



Reference: Rushmer, R. F. 1955. Cardiac diagnosis. W. B. Saunders, Philadelphia. p. 272.

Definitions: P wave = first upward deflection in the electrocardiogram; period of atrial excitation. PR interval = period measured from the beginning of the P wave to the beginning of the QRS complex; the time required for excitation to go from the sino-atrial node through the atrial musculature (through the junctional tissues and Purkinje system) to the ventricular muscle. QRS interval = period measured from the beginning to the end of the QRS complex; the time required for excitation waves to spread through ventricular walls. QT interval = duration of ventricular systole; period of uniform ventricular excitation and return of ventricles to resting or excitable state. QT_c = QT interval divided by the square root of the cycle length.

Part I: GRAPHIC



milliseconds

Reference: Rushmer, R. F. 1955 Cardiac diagnosis. W. B. Saunders, Philadelphia. p. 239.

Part II. TABULAR

Values are given in milliseconds. Those in parentheses are ranges, estimate "c" (lines 1-13, 19, 24, 33, 38) and estimate "b" (lines 14, 16-18, 20-23, 25-27, 31, 39) (cf. Introduction).

	Animal (A)	P Wave (B)	PR Interval (C)	QRS Interval (D)	QT_c (E)	Reference (F)
	Man					
1	Birth-1 da	51(40-64)	99(80-120)	65(40-100)	421(366-533)	1
2	1 da-1 wk	48 5(36-64)	95(80-120)	56(40-80)	402(322-476)	1
3	1 wk-1 mo	48(40-60)	95(80-120)	55(40-70)	385(345-434)	1
4	1-3 mo	48(40-64)	96(80-160)	62(50-80)	397(304-500)	1
5	3-6 mo	54(48-64)	101(80-120)	68(50-80)	392(348-458)	1
6	6 mo-1 yr	59 8(40-70)	106(80-140)	65(40-80)	408(350-455)	1
7	1-3 yr	65(48-88)	113(80-160)	64(40-80)	394(338-435)	1
8	3-5 yr	72(40-96)	125(100-160)	71(40-90)	402(349-465)	1
9	5-8 yr	72(50-96)	134(100-180)	72(40-90)	414(350-514)	1
10	8-12 yr	77(50-96)	139(100-200)	75(50-96)	419(350-536)	1
11	12-16 yr	82.5(60-104)	149(100-200)	77(40-100)	408(302-455)	1
12	Adult ♂	90(70-120)	160(110-210)	83(50-100)	397(337-433)	2-5
13	Adult ♀	90(70-120)	160(110-210)	72(50-100)	415(380-456)	3-6
14	Ass	80	200	60	430(400-460)	7
15	Cat	40	80	30	180	7
16	Cattle, ♂	80	180(160-200)	50	310(300-320)	7
17	Cattle, ♀	110(100-120)	225(220-230)	80	350(260-440)	7
18	Dog	70(60-80)	120(110-130)	75(70-80)	220(200-240)	7
19	Elephant		350(280-410)	150(120-180)	600(590-790)	8,9
20	Goat	80	130(120-140)	50	290(260-320)	7
21	Guinea pig	40	65(60-70)	30	120	7
22	Hamster		43(40-46)	21(19-23)		10
23	Horse	195(170-220)	370(320-420)	100(80-120)	520(440-600)	7
24	Monkey		71(54-88)	31(20-44)	212(160-264)	11
25	Mouse, white		43(39-47)	22(20-24)		10
26	Mouse, wild		32(27-37)	22(20-24)		10
27	Pig		130(120-140)	60	250(220-280)	7
28	Rabbit	40	60	30	120	7
29	Rat, white		42	10	70	12
30	Sheep	80	80	40	240	7
31	Spermophile		48(38-58)	28(26-30)		10
32	Whale, beluga		320	(90-120)		13
33	Chicken	41(35-47)	79(72-80)	23.3(20-27)		14
34	Duck		90	28		15
35	Pigeon		69	21		15
36	Sea gull		48	26		15
37	Frog		440	200	1550	16
38	Elasmobranch		250(200-440)	50(40-160)	750(400-1000)	17
39	Teleost		190(120-260)	50(40-60)		17

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70. AMPLITUDES OF ELECTROCARDIOGRAPHIC WAVES VS AGE: MAN

Values are in millimeters. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Age	Wave				
		P	Q	R	S	T
	(A)	(B)	(C)	(D)	(E)	(F)
	Lead I					
1	Birth-1 da	0.82(0-1.80)	0.3(0-0.5)	1.5(0-5.5)	6.4(0-12.5)	2.0(0-3.0)
2	1 da-1 wk	0.88(0-1.80)	0.8(0-1.0)	2.0(0-6.0)	5.0(0-10.0)	1.0(0.6-3.0)
3	1 wk-1 mo	0.90(0-1.80)	1.0(0-3.0)	3.5(1.0-8.5)	4.6(0-9.3)	2.1(1.0-4.0)
4	1-3 mo	0.37(0-2.00)	1.1(0-2.5)	6.0(2.0-14.0)	3.6(0-9.0)	2.2(0.2-4.3)
5	3-6 mo	1.00(0-2.00)	1.2(0-2.0)	7.8(2.0-13.0)	3.3(0-7.0)	2.6(0.2-5.2)
6	6 mo-1 yr	1.05(0.50-2.50)	1.6(0-4.5)	8.0(3.0-17.0)	3.7(0-10.0)	2.4(1.0-6.0)
7	1-3 yr	1.10(0.50-2.50)	1.5(0-3.0)	8.0(3.0-17.0)	3.1(0-8.0)	2.9(1.0-6.6)
8	3-5 yr	1.07(0.50-2.00)	1.2(0-2.0)	6.5(3.0-16.0)	2.1(0-6.0)	2.5(1.0-6.0)
9	5-8 yr	1.05(0 50-2.00)	1.1(0-2.5)	6.2(1.0-15.5)	2.0(0-7.0)	2.6(1.0-5.5)
10	8-12 yr	1.01(0-2.00)	1.3(0-3.0)	6.5(1.0-16.0)	1.5(0-8.0)	2.9(1.0-6.0)
11	12-16 yr	0.94(0-2.00)	1.0(0-3.0)	5.9(0-12.0)	1.3(0-10.0)	2.5(1.0-6.0)
12	16-20 yr	0.66(0.20-1.00)	0.3(0-1.3)	4.3(1.8-9.5)	1.0(0-3.2)	2.1(0.2-3.7)
13	20-30 yr	0.74(0.20-1.20)	0.2(0-1.4)	4.9(0.9-11.2)	1.0(0-4.9)	2.5(0.4-5.6)
14	30-40 yr	0.74(0.15-1.15)	0.3(0-1.6)	5.3(0.7-11.3)	1.0(0-3 6)	2.2(0.6-4.2)
15	40-50 yr	0.70(0.20-1.10)	0.3(0-1.7)	5.6(1.6-9.8)	0.8(0-4.0)	2.2(0.5-4.2)
16	>50 yr	0.72(0.45-0.94)	0.3(0-1.1)	5.5(2.2-11.7)	1.0(0-6.4)	1.8(0.9-3 3)
	Lead II					
17	Birth-1 da	1.45(0-2.50)	1.5(0-5.0)	5.5(0-23.0)	2.0(0-7.0)	1.0(-1.0 to 3.0)
18	1 da-1 wk	1.80(0-2.80)	1.8(0-4.0)	5.0(2.0-12.0)	2.3(0-8.0)	1.6(0-4.0)
19	1 wk-1 mo	1.50(0.50-2.00)	1.6(0-4.0)	7.5(2.0-14.0)	1.4(0-6.5)	2.7(0-5.6)
20	1-3 mo	1.50(0.50-2.00)	1.8(0-5.0)	11.5(5.0-19.0)	1.9(0-6.0)	3.1(0.5-5.6)
21	3-6 mo	1.60(0 50-2.50)	2.3(0-5.5)	13.5(3.0-23.0)	1.7(0-6.0)	3.4(0.2-6.7)
22	6 mo-1 yr	1.70(0-2.50)	2.4(0-5.0)	13.0(2.5-25.0)	2.2(0-6.0)	3.2(0.3-5.8)
23	1-3 yr	1.60(0.50-3.00)	2.1(0-4.5)	12.5(1.5-23.0)	1.6(0-6.0)	3.0(0.2-5.7)
24	3-5 yr	1.66(0.50-3.00)	1.6(0-4.5)	12.5(3.0-21.0)	1.3(0-5.0)	3.1(0.1-5.9)
25	5-8 yr	1.72(0 50-3.00)	1.4(0-5.0)	12.5(3.5-21.5)	1.7(0-6 0)	3.3(0.6-5 9)
26	8-12 yr	1.54(1.50-3.00)	1.4(0-3.0)	13.5(4.0-23 5)	1.5(0-6 0)	3.6(-0.5 to 8.2)
27	12-16 yr	1.62(1.00-3.00)	1.2(0-2.5)	13.5(3.5-24.5)	1.4(0-7.0)	3.3(-0 2 to 6.7)
28	16-20 yr	0.96(0-2.10)	0.4(0-2.8)	9.5(2.9-15.8)	1.6(0-6.3)	2.7(0.2-5.7)
29	20-30 yr	1 01(0.20-2.19)	0.3(0-1.9)	8.8(0.5-17.2)	1.3(0-8 2)	2.9(0.5-6.1)
30	30-40 yr	0 98(0-1.90)	0.3(0-1.8)	7.1(1.8-16.8)	1.2(0-4.9)	2.6(0.6-5 5)
31	40-50 yr	0.99(0-1.90)	0.3(0-2.2)	6.9(2.1-15.3)	1.1(0-4.7)	1.9(0.3-4.2)
32	>50 yr	1.00(0.66-1 30)	0.2(0-1 2)	6.5(2.4-14.0)	0.8(0-3.1)	2.4(1.1-5.2)
	Lead III					
33	Birth-1 da	0 62(-1.00 to 2.00)	2 5(0-9.0)	9.0(2.0-23.0)	0.2(0-3.0)	1 0(-1.2 to 3.0)
34	1 da-1 wk	0.82(0-2.00)	2 5(0-5.0)	7.5(3.0-15.0)	0.3(0-4.0)	0.5(-2.3 to 3.1)
35	1 wk-1 mo	0.80(-0.50 to 2.00)	2.4(0-5.0)	7.9(2.0-17.0)	0.2(0-2.0)	0.6(-2 2 to 3.5)
36	1-3 mo	0.65(-1.00 to 2.00)	3.3(0-7.0)	8.5(4.0-15.0)	0 6(0-5.0)	0.9(-1 7 to 3.7)
37	3-6 mo	0.81(0-2.00)	4.5(0-9.0)	10.2(3.0-22.0)	0.6(0-6.0)	1.2(-2.1 to 4.6)
38	6 mo-1 yr	0.85(0-2.00)	4.1(0-8.0)	9.8(2.0-22.0)	0.8(0-6 0)	0.7(-2 7 to 4.0)
39	1-3 yr	0.74(-1.50 to 2.00)	3.5(0-8.0)	7.5(1.0-19.0)	0.8(0-8 0)	0.2(-3 2 to 3.6)
40	3-5 yr	0.58(-1.00 to 2.00)	2.5(0-6.0)	8.5(1.0-18.0)	0.8(0-7 0)	0.3(-2 2 to 3 4)
41	5-8 yr	0.65(-1.00 to 2.00)	2.2(0-5.5)	8 5(1 0-20.0)	0.8(0-8 0)	1.6(-2 2 to 4.4)
42	8-12 yr	0.55(-1.50 to 2 00)	1.9(0-5 0)	9 2(1.0-24 0)	1 0(0-5 0)	0.7(-1 8 to 3.5)
43	12-16 yr	(-0.50 to 2.00)	1.6(0-5.0)	9.0(1.0-26.0)	1.0(0-9.0)	0.8(-1 6 to 3 5)
44	16-20 yr	0 43(-1.00 to 1.80)	0.6(0-4.6)	6.2(1.2-15.0)	1.2(0-4 9)	0.8(-1.9 to 3.9)
45	20-30 yr	0.48(-0.75 to 2.00)	0.5(0-3.1)	5.3(0-16.4)	1.1(0-7.3)	0.7(-2 0 to 3.8)
46	30-40 yr	0.42(-0.73 to 1.30)	0.4(0-2.8)	3.8(0.3-13 1)	1.2(0-5.5)	0.5(-0 6 to 3 1)
47	40-50 yr	0.48(-0 65 to 1.42)	0.3(0-1.9)	3.3(0.6-12.7)	1.6(0-8.8)	0 2(-1 9 to 3.2)
48	>50 yr	0.58(0-1.42)	0.4(0-1 4)	3.3(0 8-11.0)	1.5(0-7.4)	0 7(-0.8 to 2.2)
	Lead aVR					
49	Birth-1 da	-0.90(-2.00 to 1.50)	2.4(0-4.0)	3.9(0-9.0)	0.3(0-9.5)	-0 5(-3 2 to 2.4)
50	1 da-1 wk	-1.23(-2 00 to 0)	2.7(0-4 0)	2.7(0-7.0)	1.9(0-7 0)	-1.6(-3 2 to 0)
51	1 wk-1 mo	-1.03(-2.00 to 1.00)	4 0(0-9.0)	2.2(0-6.0)	2.0(0-8 0)	-2 3(-3 9 to -0.6)
52	1-3 mo	-1.12(-2.00 to 0)	7.1(0-12 0)	2 1(0-4 0)	4 3(0-14 5)	-2.3(-4 7 to -0 2)
53	3-6 mo	-1.06(-2.00 to 0)	8.0(0-12.0)	1 8(0-5.0)	6.0(0-15.0)	-2.9(-4 5 to -0 3)
54	6 mo-1 yr	-1.22(-2.50 to 0)	8.1(0-13.0)	2.3(0-5.0)	5 0(0-18.0)	-2 8(-5 1 to -0 4)
55	1-3 yr	-1.31(-2.00 to 0)	7.3(0-14.0)	2.2(0-6.0)	5.0(0-15 0)	-2 9(-5 2 to -0 6)
56	3-5 yr	-1.20(-2.00 to -1 00)	7.4(0-13.5)	1.7(0-5.0)	5.0(0-14 0)	-2 6(-5 6 to -0 5)
57	5-8 yr	-2.00(-2.08 to 0)	8.2(0-13.0)	1.6(0-5.0)	5.2(0-15 0)	-2.6(-4 9 to -0.6)
58	8-12 yr	-1.24(-2.50 to -0.50)	8 2(0-12.5)	1.3(0-4.0)	1 0(0-16 0)	-3.2(-5 3 to -0.7)
59	12-16 yr	-1.14(-2.00 to -0.50)	7.9(0-14 0)	1.2(0-3.0)	0.8(0-14.0)	-2.9(-5 2 to -0 5)

70. AMPLITUDES OF ELECTROCARDIOGRAPHIC WAVES VS AGE: MAN (Continued)

	Age (A)	P (B)	Q (C)	R (D)	S (E)	T (F)
		Lead aVR (concluded)				
60	16-20 yr	-0 84(-1.75 to -0 25)	2.1(0-8.9)	1 9(0-4.7)	4.3(0-11.1)	-1.9(-4 8 to -0.1)
61	20-30 yr	-0 78(-1.54 to -0 10)	2.5(0-11.2)	1.1(0-3 6)	3.4(0-11.1)	-2.7(-5.3 to -0.6)
62	30-40 yr	-0 81(-1.79 to -0.10)	2.1(0-9.0)	1.0(0-3.3)	3.5(0-14.7)	-2.4(-5.4 to -0.3)
63	40-50 yr	-0 79(-1.38 to -0 28)	2.0(0-8.5)	0.9(0-4.1)	3.5(0-13.2)	-2.3(-4.7 to -0.2)
64	>50 yr	-0 89(-1.15 to 0.54)	2.9(0-10 2)	1.0(0-2.8)	2.9(0-9.5)	-2.2(-4 6 to -1.5)
		Lead aVL				
65	Birth-1 da	0 10(-1.50 to 1.50)	1.3(0-2 0)	2 0(1.0-6 0)	6.5(0-16 0)	0(-2 4 to 2 6)
66	1 da-1 wk	0.11(-1.50 to 1 00)	0.7(0-1.0)	1.6(0-3.0)	5 5(0-13.0)	0.9(-0.8 to 2.7)
67	1 wk-1 mo	0 26(-1.00 to 1 50)	1.3(0-1.5)	2.3(0-7.0)	6.0(0-11.0)	1.0(-1.2 to 3.1)
68	1-3 mo	0 18(-1.00 to 1 00)	1.7(0-2.0)	3 6(1.0-9.0)	4.8(0-9 5)	0.7(-1.5 to 3.1)
69	3-6 mo	0.35(-0.50 to 1.00)	1.1(0-1.5)	3.9(0-8.0)	4.0(0-7.0)	0.8(-0.6 to 2 4)
70	6 mo-1 yr	0 29(-1.50 to 1 00)	1.8(0-5.5)	4 6(1.0-10.0)	4 2(0-11.0)	1.2(-1.0 to 3.6)
71	1-3 yr	0 36(-1.00 to 1.00)	1.3(0-4 0)	4.3(1.0-10.0)	3 8(0-9 0)	1.4(-0.5 to 3.4)
72	3-5 yr	0.44(-1.00 to 1.00)	1.3(0-3 0)	3.3(0-7.0)	3.3(0-10.0)	1.2(-1.0 to 3.6)
73	5-8 yr	0.30(-1 00 to 1.50)	1.2(0-4.0)	2.6(0-7.0)	3 2(0-10.0)	1.0(-1.2 to 3.3)
74	8-12 yr	0.47(-1 00 to 1.00)	1.2(0-6.0)	2.7(0-8.0)	3 0(0-14 0)	1.3(-0.7 to 3.6)
75	12-16 yr	0.28(-1.00 to 1.00)	1.3(0-6 0)	2.4(0-12.0)	3 0(0-20 0)	1.1(-1.1 to 3.6)
76	16-20 yr	0 25(-0 85 to 1.42)	0 3(0-2.3)	1 9(0 2-5 8)	2.0(0-7.7)	0.6(-1.8 to 3.6)
77	20-30 yr	0 22(-0 95 to 1.22)	0.3(0-3.5)	2.2(0-7.6)	2.1(0-10.1)	0.9(-1.5 to 3.7)
78	30-40 yr	0 71(-0 85 to 1.40)	0.3(0-2.2)	2.6(0-7.5)	1.3(0-9.0)	0.9(-1.6 to 2.7)
79	40-50 yr	0 77(-0.95 to 1.35)	0.3(0-1.3)	3.2(0.3-10.1)	1.4(0-11.3)	0.9(-1.9 to 3 0)
80	>50 yr	0 07(-0.95 to 0.70)	0.4(0-1.5)	2 7(0 4-5 7)	1.4(0-6.3)	0.6(-1.1 to 2.7)
		Lead aVF				
81	Birth-1 da	1.06(-1.00 to 2.00)	1.9(0-6.0)	6 5(2.0-20 0)	0.8(0-7.0)	0.9(-1.2 to 3 0)
82	1 da-1 wk	1.18(0-2 00)	2.0(0-4.0)	5.8(2.0-13 0)	0.7(0-3 0)	0.2(-1 6 to 3.8)
83	1 wk -1 mo	1.23(-1 00 to 3.00)	1.9(0-4.0)	6.8(2 0-15.0)	0.5(0-5.0)	0.5(-0.5 to 3.7)
84	1-3 mo	1 16(0-2 00)	2.5(0-5.0)	8.8(0 5-17.8)	0 8(0-4.0)	2 0(-0.1 to 3.9)
85	3-6 mo	1 13(0 50-2 00)	2.7(0-6 0)	10.1(0.5-20 2)	0.9(0-6.0)	2.2(0-4.2)
86	6 mo-1 yr	1 25(0-2 00)	2.9(0-6 0)	9.4(0-17.2)	1.1(0-4.0)	1.9(-0.1 to 3.7)
87	1-3 yr	1 24(0-2 00)	2 2(0-5 0)	8.2(1 0-20 0)	0.8(0-5 0)	1.7(-0.6 to 4.1)
88	3-5 yr	1 15(0-2.00)	1.7(0-5 0)	9 8(0 5-18.8)	0.7(0-3 5)	2.1(-0.7 to 4.9)
89	5-8 yr	1 24(0-2.00)	1.5(0-5 0)	9.7(0.5-18.7)	0.9(0-7.0)	2.0(-0 6 to 4.5)
90	8-12 yr	1 12(0-2 00)	1.5(0-3.0)	10 2(0.7-20 0)	1.0(0-5.0)	2.3(-0.5 to 4.7)
91	12-16 yr	1 18(0-2 00)	1.3(0-3.0)	10 5(0.1-21.8)	1.0(0-4 0)	2.4(-0.7 to 5.4)
92	16-20 yr	0.76(-0.80 to 1.80)	0.4(0-3 8)	7 7(1.8-14.0)	1.3(0-4.9)	1.9(-0.5 to 5 4)
93	20-30 yr	0 71(-1.77 to 1.61)	0 4(0-2.8)	6 8(0.6-16 1)	1.0(0-5.9)	2.4(-0.6 to 5 2)
94	30-40 yr	0 77(-0.60 to 1 60)	0.3(0-1.9)	5.3(0 2-14 8)	1.0(0-7.1)	1.7(-0.4 to 4.6)
95	40-50 yr	0 73(0-1 52)	0 3(0-1.8)	4.5(0.5-12 1)	1 1(0-5 2)	1.4(-0.5 to 4.0)
96	>50 yr	0 74(-0 30 to 1 25)	0 3(0-1 0)	4.0(0.8-13.2)	0.8(0-3 2)	1.6(0.3-4.9)
		Lead V_1				
97	Birth-1 da	0 96	0	16 0(6 0-27.0)	10.0(0-28 0)	0 6(-4.0 to 5.0)
98	1 da-1 wk	1 10	0	17 0(4.0-30 0)	11.0(4 0-25.0)	-3.6(-6.0 to -2.0)
99	1 wk-1 mo	0 63(-1.00 to 2 00)	0	13.5(2 6-24 0)	7.0(0-17.0)	-2.8(-8 0 to -0.8)
100	1-3 mo	0 42(-1.00 to 1.50)	0	10 0(1.5-19.0)	6.5(0-20.0)	-2.7(-7.0 to 2.0)
101	3-6 mo	0.39	0	12.0(5 0-19.0)	7.0(3.0-12.0)	-4.2(-7.5 to -0.4)
102	6 mo-1 yr	0 73(-1 00 to 1 00)	0	12.8(1.5-20 0)	8 0(3 0-18.0)	-3.9(-7.4 to 0)
103	1-3 yr	0 81(-1 00 to 2 00)	0	9.0(3 9-18.0)	7.0(0-28.0)	-3 7(-6.0 to -2.0)
104	3-5 yr	1 03	0	7.0(2 0-16 0)	13.0(6.0-33.0)	-3.8(-6 2 to -1.0)
105	5-8 yr	0 94	0	7.0(1.2-20.0)	14.0(4.0-26.0)	-3 5(-6.0 to -0 8)
106	8-12 yr	0 68	0	6 0(1.8-16.0)	13 0(5 0-26 0)	-2.9(-5.6 to -0.5)
107	12-16 yr	0 69	0	5 5(0-16.0)	14.5(5 0-26.0)	-1.5(-4.0 to 7.0)
108	16-20 yr	0 65(-0.22 to 2.20)	0	4 6(0 4-16.7)	11 7(1 8-25 1)	0.7(-3.3 to 6.0)
109	20-30 yr	0 62(-1 11 to 1 80)	0	3.7(0.07-11.80)	11.5(2.5-26.2)	1.3(-3.6 to 7.6)
110	30-40 yr	0 61(-0 80 to 1 80)	0	3.3(0-9 4)	8.4(0.8-21.3)	0.9(-2.0 to 12.2)
111	40-50 yr	0 46(-0 70 to 1.20)	0	3 2(2.2-10.6)	9 3(0 9-20.0)	1.1(-2.3 to 5.6)
112	>50 yr	0 38(-0.38 to 1.40)	0	2.3(0 8-15.5)	7.3(2.0-17.3)	0 6(-1.7 to 3 7)
113	Birth-1 da	1 05				
114	1 da-1 wk	1 22				
115	1 wk-1 mo	1 30(0 50-2 0[illegible]				
116	1-3 mo	0 81				
117	3-6 mo	1 36(0 50-2 0[illegible]				
118	6 mo-1 yr	1 00				
119	1-3 yr	1 39				
120	3-5 yr	1 05	0	13 5(1 0-25 0)	22.0(16 0-34.0)	-4 1(-7.0 to -1.0)

70. AMPLITUDES OF ELECTROCARDIOGRAPHIC WAVES VS AGE: MAN (Continued)

	Age	Wave				
		P	Q	R	S	T
	(A)	(B)	(C)	(D)	(E)	(F)
				Lead V_2 (concluded)		
121	5-8 yr	1.00	0	12.0(1.0-26.0)	23.0(11.0-40.0)	-1.2(-6 0 to 6 0)
122	8-12 yr	0.94	0	10.0(1.0-20.0)	23.0(12.0-40.0)	1.0(-7.5 to 10.0)
123	12-16 yr	0.97	0	8.5(2.0-20.5)	23.0(8.0-51.0)	6.0(0.8-13.0)
124	16-20 yr	0.63(-0.22 to 1.45)	0	7.3(0.5-20.2)	16.2(2.6-45.5)	3.5(-3.8 to 14.1)
125	20-30 yr	0.63(-0.72 to 1.50)	0	6.3(0.4-15.2)	17.4(2.40-39.15)	4 0(-2.6 to 17.8)
126	30-40 yr	0.63(0.15-1.55)	0	5.4(0.4-15.2)	13.0(1.9-27.4)	3 6(-1.4 to 14.4)
127	40-50 yr	0.48(-0.40 to 1.20)	0	5.4(0.6-13.4)	12.4(1.9-25.4)	3.5(-1.0 to 10.7)
128	>50 yr	0.38(-0.38 to 1.20)	0	4.7(1.2-11.0)	8.7(2 4-19.2)	2.6(-1.6 to 6.2)
				Lead V_3		
129	Birth-1 da	1.70(1.00-3.00)	0(0-0)	20.0(11.0-29.0)	26.0(12.0-36.0)	-4.0(-7.0 to 4.0)
130	1 da-1 wk	1.88(1.00-3.00)	0.1(0-3.0)	20.0(5 0-35.0)	19.0(0-36.0)	-1.5(-5.0 to 4.0)
131	1 wk-1 mo	1.40	0.1(0-1.0)	20 2(3.0-37.0)	14.0(2.0-26.0)	-0.5(-4 0 to 6.0)
132	1-3 mo	0.94	0.2(0-1.0)	22.5(12.0-33.0)	15.0(5.0-25.0)	-0.2(-7.0 to 3.0)
133	3-6 mo	1.50(0.50-2.50)	0.1(0-1.0)	21.0(12.0-31.0)	16.0(0-32.0)	-0.3(-5 0 to 4.0)
134	6 mo-1 yr	1.28(1 00-2.00)	0(0-3)	19.0(9.0-29.0)	13.5(2.0-26.0)	-2.5(-5.0 to 2.0)
135	1-3 yr	1.15	0.2(0-1.0)	17.0(10.0-33.0)	14.5(6.0-25.0)	-1.5(-7.0 to 7.0)
136	3-5 yr	0.98	0(0-0)	16.0(6.0-27.0)	13.0(4 0-24.0)	0.5(-4.0 to 4 0)
137	5-8 yr	0.92(0-1.50)	0.1(0-1.0)	14 5(4.0-30.0)	16.0(2.0-31.0)	1.8(-6.0 to 11.0)
138	8-12 yr	0.90(0-1.50)	0.05(0-0.5)	11.5(2.0-30.0)	15.5(1.0-30.5)	2.4(-8.0 to 6.0)
139	12-16 yr	0.95(0-1.50)	0(0-0)	11 2(2.0-26.0)	13.0(3.0-34 0)	5 5(1.5-13.0)
140	16-20 yr	0.63(0-1.81)	0.08(0-0.2)	8.5(1.6-23.3)	10.7(0.9-28.9)	4.2(-3.7 to 13.5)
141	20-30 yr	0.61(0-1.60)	0.02(0-0.4)	8.0(0.7-24.1)	12.0(0.5-77.5)	5.7(-0 8 to 15.2)
142	30-40 yr	0.65(0-1.80)	0.01(0-0.5)	7.9(0.6-22.4)	9.6(0.9-22.2)	4.4(0-16.0)
143	40-50 yr	0 45(-0.50 to 1.45)	0.01(0-0.4)	7.6(1.4-22.3)	9.2(0.4-20.0)	4.4(0-12.3)
144	>50 yr	0.61(-0.16 to 2.00)	0.01(0-0.1)	8.0(2.2-16.4)	6.0(1.5-17.2)	4 0(0-9.5)
				Lead V_4		
145	Birth-1 da	1.08(0.50-2.00)	0.3(0-2.5)	19.0(6.0-32.0)	23.0(2.0-44.0)	-0.6(-7.0 to 3.0)
146	1 da-1 wk	1 03(0.50-1 50)	1.0(0-5.0)	20.0(7.0-35.0)	13 0(1.0-30.0)	2.5(-2.0 to 6 5)
147	1 wk-1 mo	1.17(0 50-1.50)	1.0(0-4.0)	19.0(6 0-37.0)	9.0(2 0-18.0)	3.2(0.5-6.5)
148	1-3 mo	0.87(0.50-1 50)	1.4(0-3.0)	21 0(9 0-33.0)	11.5(0-22.0)	3.0(-1.5 to 7.2)
149	3-6 mo	1.00(0.50-1.50)	1.8(0-2.5)	21.5(8.0-36 0)	8.0(0-22.0)	3.2(0.4-6.8)
150	6 mo-1 yr	1.25(0-2.00)	1.6(0-3.0)	25.0(14 0-35.0)	11.0(0-27.0)	3.0(-2.0 to 8 0)
151	1-3 yr	1.09(0.50-1.50)	2.5(0-5 0)	22 0(10.0-40.0)	7 5(0-19.0)	4.5(-1.6 to 11.0)
152	3-5 yr	0.87(0 50-1 50)	1 7(0-5.0)	24 0(12.0-42.0)	6.5(1.0-18.0)	4.8(-1.2 to 10.5)
153	5-8 yr	0.84(0-1 50)	1.6(0-5.0)	25 5(15.0-50.0)	8.0(1.0-20.0)	5 8(-0.8 to 11.5)
154	8-12 yr	0.85(0-1.50)	1.8(0-4 5)	25 0(2 5-50.0)	7.0(1.5-20.0)	5.6(-0.2 to 11.2)
155	12-16 yr	0.80(0-1.50)	0.5(0-3.0)	30.0(6.0-51 0)	6.5(1.0-17.0)	7 2(0-15 0)
156	16-20 yr	0.56(0-1.33)	0.05(0-0.6)	11.7(3.1-30 1)	6 3(0 2-14 2)	4.7(-3 6 to 12.6)
157	20-30 yr	-0.62(-0.20 to 2 00)	0.1(0-2.0)	13.1(3.8-34.7)	7 2(0-28.8)	6.0(0.7-14 2)
158	30-40 yr	0.64(0.10-2.30)	0.1(0-1 6)	11.9(1 8-32.0)	6.3(0.2-20.9)	4 6(-0 5 to 13.1)
159	40-50 yr	0.48(0-1 20)	0.1(0-1.1)	11.6(2 0-22.5)	6 1(0-18.3)	4 6(0-11.1)
160	>50 yr	0 59(0.16-1.75)	0.07(0-0 5)	12.0(4.4-17.6)	4 5(0.2-15 3)	3 8(0.1-8.5)
				Lead V_5		
161	Birth-1 da	1.30(1 00-2 00)	2.2(0-5.5)	12.0(0-24.0)	11 0(0-30.0)	1.5(-3 8 to 6.3)
162	1 da-1 wk	1.00(0.80-2.00)	2.0(0-5.0)	12 0(2-28 0)	8.0(0-18.0)	2 9(0.5-5.6)
163	1 wk-1 mo	1 13(1.00-2.00)	2.0(0-4 5)	13 5(4.0-34.0)	6.0(0-14 0)	3.4(0.5-5.7)
164	1-3 mo	0 75(0.50-1 00)	2 0(0-3 0)	14.5(6.0-24.0)	5.5(0-14 0)	3 6(1.0-6.3)
165	3-6 mo	1.12(1.00-1.50)	2.1(0-3.5)	19.5(9.0-30 0)	5 0(0-15 0)	3 7(0.2-7.6)
166	6 mo-1 yr	0.88(0-1.50)	2.3(0-5.0)	18.5(9.0-27 0)	3.0(0-9 0)	3 6(0.8-6 2)
167	1-3 yr	0.97(0.50-1 50)	2 3(0-4.0)	19 0(11.0-39 0)	3.0(0-9 0)	4.3(0.2-8.3)
168	3-5 yr	0.83(0 50-1.00)	2.1(0-5.0)	20.0(10.0-34.0)	2.5(0-8 5)	4.5(0.6-8.5)
169	5-8 yr	0.75(0-1.50)	1.9(0-7.0)	22.0(13 0-39.0)	3.0(0-9 0)	5 7(0-11 0)
170	8-12 yr	0 73(0-1.50)	1.9(0-4.5)	22.5(10 0-36.0)	3 0(0-11 5)	5.8(0.5-11 0)
171	12-16 yr	0.76(0-1.00)	1.3(0-4 0)	18.0(5.0-31 0)	3.0(0-7 5)	5 9(0 5-11 5)
172	16-20 yr	0.54(0-1.10)	0.5(0-2.8)	11.4(4.1-26 5)	2.2(0-8 1)	3 4(0 2-10.54)
173	20-30 yr	0.56(0-2.00)	0 4(0-3.0)	11.3(3 0-28.4)	2 3(0-16.0)	4 1(0 8-8.3)
174	30-40 yr	0.60(0-2.40)	0.5(0-2 1)	11 4(4.2-24 2)	2 6(0-9 7)	3 5(0-9 6)
175	40-50 yr	0.47(0-1 00)	0.5(0-2 5)	10.6(4 2-20 7)	1 7(0-8 8)	3 3(0-9.2)
176	>50 yr	0.56(0 16-0.95)	0 4(0-1 4)	10.2(0 4-17 0)	1.5(0-6.5)	3 1(0 7-7 5)
				Lead V_6		
177	Birth-1 da	0.89(0-2.00)	1.3(0-2 0)	4.5(0-8 0)	3 5(0-13 0)	1 3(0 8-3 4)
178	1 da-1 wk	0.78(0.50-1 50)	1 3(0-2.0)	6 5(1.0-16 0)	3 2(0-13 0)	1 9(0 3-3 6)
179	1 wk-1 mo	0.90(0.50-1.00)	1.4(0-2 0)	8 5(1 0-24 0)	2.6(0-10.0)	2.7(0 1-5.6)
180	1-3 mo	0.81(0 50-1.00)	1.4(0-3.5)	9 5(3 0-16 0)	2.0(0-6 0)	2.7(0 6-4 8)

70. AMPLITUDES OF ELECTROCARDIOGRAPHIC WAVES VS AGE: MAN (Concluded)

	Age	Wave				
		P	Q	R	S	T
	(A)	(B)	(C)	(D)	(E)	(F)
		Lead V_6 (concluded)				
181	3-6 mo	0.79(0-1.50)	1.8(0-4.0)	10.0(0.5-17.0)	1.7(0-5.0)	2.7(-0.5 to 6 0)
182	6 mo-1 yr	0 84(0-1.50)	2 4(0-5 0)	13.0(4.5-21.0)	2.0(0-3.0)	2.9(0.7-5.0)
183	1-3 yr	0 84(0.50-1.50)	1.7(0-4.5)	12.0(2.5-21 5)	1.2(0-4 0)	3.3(0.6-5 6)
184	3-5 yr	0.75(0.50-1.00)	1.8(0-4 0)	13 0(3 5-22.0)	0.7(0-3.0)	3.6(0.8-6.4)
185	5-8 yr	0.74(0-1.50)	1.7(0-5 0)	14 0(6.5-21.5)	0.9(0-5.0)	4.0(0.3-7.7)
186	8-12 yr	0.70(0-1.50)	1.7(0-4 0)	13.5(10.0-22.0)	1.1(0-3.0)	4.4(0.5-8.4)
187	12-16 yr	0.66(0-1.50)	1 3(0-2.5)	13.5(7.0-21.0)	1.2(0 2-5 0)	4.0(0 8-7.2)
188	16-20 yr	0.50(0-1.00)	0 6(0-4.2)	9.8(3.5-24.4)	1.5(0-11.2)	2.9(0-7.1)
189	20-30 yr	0.53(0-1.80)	0.5(0-2.6)	10.7(2.2-22.6)	1.6(0-14.3)	3.3(0.5-6 9)
190	30-40 yr	0.56(0-1.90)	0 4(0-2.7)	9.4(2.5-26.0)	1.3(0-8.4)	2 8(0-6.7)
191	40-50 yr	0.46(0-1 11)	0.4(0-2.6)	8.8(3.6-19 0)	0.9(0-7.0)	2.8(0-6.8)
192	>50 yr	0.52(0.16-0 95)	0.4(0-1.1)	8 6(2.0-15.5)	0 8(0-4 7)	2.5(0.7-5 6)

Contributor: Lepeschkin, Eugene

References: From birth-16 yr: [1] Ziegler, R. F. 1951. Electrocardiographic studies in normal infants and children. C. C. Thomas, Springfield, Ill. [2] Nadrai, A. 1938. Zschr. Kinderh. 60 285. [3] Romeiro-Neto, M. M 1949 Derivacoes unipolares do precordio em criancas normais. São Paulo [4] Yu, P. N G., H. A. Joos, and C. P. Katsampas. 1951. Am. Heart J. 41:91. [5] Alimurung, M M , L. G. Joseph, A. S. Nadas, and B. F. Massell. 1951. Circulation, N Y. 4.420. From 16->50 yr: [6] Vaquero, M., R. Limon, and A. Limon 1948. Mem. II Congr. Interamer. Card 2 887.

71. R WAVE EXPRESSED AS PERCENTAGE OF RS DEFLECTION MAN

	Age	Lead					
		V_1	V_2	V_3	V_4	V_5	V_6
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Birth-1 da	62(26-96)	48(22-75)	41(25-56)	44(15-72)	43(10-77)	50(0-100)
2	1 da-1 wk	58(35-81)	48(22-75)	53(20-85)	56(12-100)	60(20-100)	65(25-100)
3	1 wk-1 mo	66(34-94)	52(29-75)	55(34-76)	63(45-78)	66(33-100)	76(30-100)
4	1-3 mo	63(27-100)	54(26-79)	56(33-81)	62(32-92)	71(45-100)	78(60-100)
5	3-6 mo	60(33-86)	57(36-76)	59(32-86)	71(50-100)	78(50-100)	86(60-100)
6	6 mo-1 yr	56(28-84)	50(21-78)	56(33-83)	70(45-100)	80(55-100)	88(70-100)
7	1-3 yr	45(32-67)	42(23-65)	54(36-83)	75(42-100)	90(56-100)	94(75-100)
8	3-5 yr	42(21-67)	40(18-63)	54(22-83)	78(52-100)	85(65-100)	95(68-100)
9	5-8 yr	35(10-55)	33(5-62)	48(12-84)	76(58-96)	86(67-100)	94(69-100)
10	8-12 yr	34(16-50)	32(10-54)	46(11-81)	75(38-96)	88(58-100)	95(80-100)
11	12-16 yr	27(10-55)	27(10-56)	49(13-85)	78(50-100)	87(70-100)	90(70-100)
12	Adults	25(0-50)	17(9-93)	42(9-90)	80(17-95)	88(50-96)	90(70-96)

Contributor: Lepeschkin, Eugene

References: From birth-16 yr: [1] Ziegler, R. F. 1951. Electrocardiographic studies in normal infants and children. C. C. Thomas, Springfield, Ill. Adults [2] Lepeschkin, E. 1951. Modern electrocardiography. Williams and Wilkins, Baltimore. v. 1.

72. AMPLITUDES OF ELECTROCARDIOGRAPHIC WAVES: FARM ANIMALS

Animals were tested in standing position. Values are in millimeters. Ranges are estimate "c" (cf. Introduction).

	Animal[1]	Wave							
		P		Q	R	S	T	
		Monophasic	Diphasic				Monophasic	Diphasic
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Lead I							
	Cattle, dairy							
1	Calf	0.3-0.5	0.3-0.5	0.6-1.2	0.2-5.5		-1.5 to 1.5	0.5-1.0
2	Cow	0.6-1.0	0.4-1.5	0.3-2.3	0.4-2.5	0.2, 5.0	-2.0 to -1.0	0.5-3.0
3	Goat	0-0.1	0.5	0.5-1.2	0.5-2.2		0.5-1.5	
4	Horse, draft	0.1-0.5	2.0	1.0	0.2-5.0	0.5	-3.5 to -1.2	2.0
5	Mule	0.1-0.5			1.0-4.0		-3.0 to 4.5	
6	Pig	0.5-1.0		1.0-1.4	1.5-4.5		-2.5 to 1.0	
7	Sheep	0.2-0.5	0.2	0.7-3.0	1.2-4.5	6.0	-3.0 to 2.0	
	Lead II							
	Cattle, dairy							
8	Calf	0.4-1.2	0.8-1.2	1.0-5.2	0.8-4.2	0.2-1.5	-3.0 to 3.2	
9	Cow	0.4-1.2	0.3, 1.2	0.4-1.9	0.7-8.0	0.2, 1.5	-3.0 to 4.0	2.0-3.5
10	Goat	0-0.2		0.4-1.2	1.3-3.0		0.7-3.0	
11	Horse, draft	0.6-3.0	3.0-4.0	0.2-1.5	1.0-9.0	0.2-1.5	-5.5 to 5.0	1.5-4 0
12	Mule	1.2-2.5			8.0-12.2	0.5-3.0	-3.0 to 2.5	
13	Pig	0.6-1.2		0.3-1.5	3.2-60	1.0	-4.0 to -2.0	1.2-4 0
14	Sheep	0.2-0.6		0.5-4.0	0.7-5.0	4.0	-4.0 to 0.5	
	Lead III							
	Cattle, dairy							
15	Calf	0.2-1.0	8.0	1.0	0.8-4.0	1.4-1.5	1.2-2.5	1.5
16	Cow	0.5-1.0	0.3	1.2-2.7	0.5-9.0	5 0	0-3.0	1.2-2.0
17	Goat	0-0 3		1.0	1.0-5.3	0.9	0.6-2.0	
18	Horse, draft	2.2-2.7		0.5-1.0	2.0-8.0	1.5-3.0	1.5-4.5	2.5-5.0
19	Mule	1.0-2.0			6.0-9.0	2.5-4.0	1.5-4.0	2.8
20	Pig	0.3-0.8		0.5-0.8	0.5-4.0	2.5	2.0-3.7	0.7
21	Sheep	0.1-0.5		0.3-3.0	0.5-4.0	2.0	-2.0 to 2.0	

/1/ Subjects: 13 calves, 10 cows, 5 goats, 13 horses, 4 mules, 6 pigs, 12 sheep.

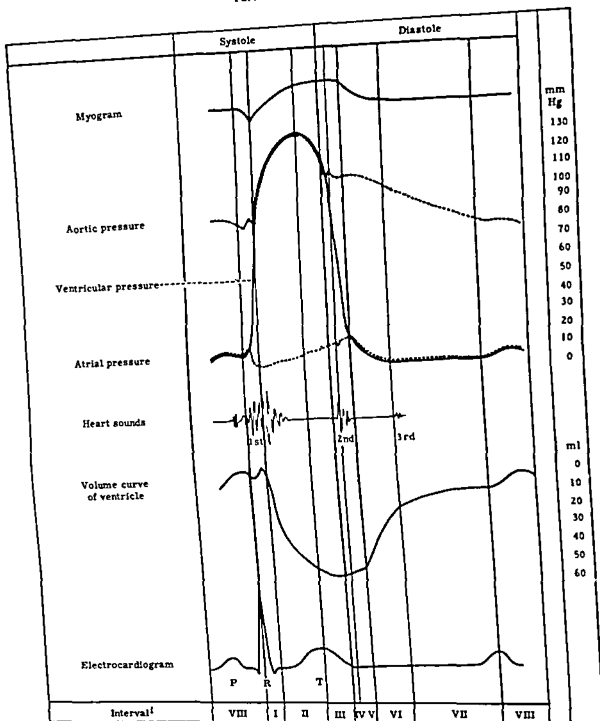
Contributor: Brody, Samuel

Reference: Platner, W. S., H. H. Kibler, and S. Brody. 1948. Missouri Agr. Exp. Sta. Res. Bull. 419, p. 9.

73. EVENTS DURING THE CARDIAC CYCLE: MAN, DOG

Relative time intervals of events within the cardiac cycle may vary with change in heart rate.

Part I. SCHEMATIC



/1/ Schematic presentation of phases of the cardiac cycle, not an exact depiction of the duration of events.

Contributor: Wiggers, Carl J.

Reference: Wiggers, C. J. 1952 Circulatory dynamics. Grune and Stratton, New York.

Part II. TABULAR

	Phase	Interval	Events at Onset of Phase	Main Events during Phase	Events at Close of Phase	Phase Duration[1] sec	
						Man	Dog
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Isometric contraction	I	Onset of ventricular contraction	Closure of atrio-ventricular valves, rapid rise of intraventricular pressure	Opening of semilunar valves	0.05	0.05
2	Maximum ejection	II	Opening of semilunar valves	Rapid outflow of blood from ventricles	Peak of intraventricular pressure	0.09	0.12
3	Reduced ejection	III	Peak of intraventricular pressure	Declining outflow of blood from ventricles	Onset of ventricular relaxation	0.13	0.10
4	Protodiastole	IV	Onset of ventricular relaxation	Rapid drop in intraventricular pressure	Closure of semilunar valves	0.04	0.02
5	Isometric relaxation	V	Closure of semilunar valves	Continued ventricular relaxation with no volume change	Opening of atrio-ventricular valves	0.08	0.05
6	Rapid inflow	VI	Opening of atrio-ventricular valves	Rapid flow of blood from atria to ventricles	Slowing of inflow rate	0.11	0.06
7	Diastasis	VII	Slowing of inflow from atria to ventricles	Continued slower flow from atria to ventricles	Onset of atrial contraction	0.19	0.29
8	Atrial systole	VIII	Onset of atrial contraction	Increased flow from atria to ventricles	Termination of atrial, and onset of ventricular, contraction	0.11	0.11

/1/ Assumed heart rate: 75 beats/min.

Contributors: (a) Gleckler, William J., (b) Soloff, Louis A.

References [1] Wiggers, C. J. 1923. Circulation in health and disease. Lea and Febiger, Philadelphia. [2] Wiggers, C. J. 1949. Physiology in health and disease. Ed. 5. Lea and Febiger, Philadelphia. [3] Rushmer, R. F. 1956. Physiol Rev. 36:400. [4] Rushmer, R F. 1955. Cardiac diagnosis. W. B Saunders, Philadelphia.

74. DURATION OF HEART SOUNDS AT VARIOUS AGES. MAN

Method. A = recorded at apex with stethoscopic microphone, B = recorded at apex with logarithmic microphone; C = recorded at aortic area with stethoscopic microphone. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Age yr	Method	Sound, sec			Interval Between 2nd and 3rd Sound sec	Reference
			1st	2nd	3rd		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	<4	A	0.085	0.055			1
2		C	0.070	0.060			
3	4-10	A	0.120	0.065	0.050	0.12[1]	1
4		C	0.145	0.110	0.040	0.14[1]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.14[1]	1
						(0.16-0.24)[2]	2
						(0.16-0.19)[2]	
						0.16[1]	1
						0.18[1]	
						0.18[1]	1
						0.19[1]	
							1

/1/ Interval between the peak of the largest oscillations of the 2nd sound and the beginning of the 3rd sound.
/2/ Interval between the beginning of the 2nd heart sound and the mid-point of the 3rd heart sound.

Contributor: Kuo, Peter T.

References: [1] Luisada, A. A., F. Mendoza, and M. M. Alimurung 1949. Brit. Heart J. 11 41. [2] Rappaport, M. B., and H. B. Sprague. 1942. Am. Heart J. 23:591.

75. CHARACTERISTICS OF FUNCTIONAL HEART MURMURS: MAN

	Variable	Area				Reference
		Pulmonary	Precordial[1]	Parasternal[2]	Mitral	
	(A)	(B)	(C)	(D)	(E)	(F)
1	Age	Children and young adults.	Children and young adults.	Children and adults.	All ages.	B,1-13;C,5-14;D,E,14
2	Intensity	Faint or loud.	Faint or loud.	Up to loud.	Loud.	B,1,2,5-13;C,5-14,D,14,15,E,14
3	Effect of posture	Louder with recumbency.	Usually louder with recumbency, but may become louder in erect position.	Little effect.	Little or variable effect.	B,5,6,C,5,6,14,D,14,E,2,14
4	Effect of respiration	Disappears or becomes faint with deep inspiration.	Either unaffected or faint with deep inspiration.	Persists with deep inspiration.	Persists with deep inspiration.	B,5,6,C,5,6,14,D,E,14
5	Position of murmur in cardiac cycle	Early or mid-systolic.	Mid-systolic.	Mid-systolic.	Late systolic (may be due to organic mitral valve incompetence).	B,1,2,5,6,C,5,6,14;D,14,E,14,b
6	Character of murmur	Usually of low intensity, blowing (may be high pitched)	Musical, vibratory, blowing, or twanging	Blowing, or rough and musical.	Blowing, rough, and partially musical.	B,1,2,5-13,C,2,5-14,D,15,E,2,14
7	Transmission of murmur	Often also audible at apex.	If loud, sometimes transmitted toward either apex or base, or both.	If loud, may be audible at base and near apex.	Audible over precordium.	B,5,6;C,5,6,14;D,E,14

/1/ Includes space immediately medial to the mitral area and extending to the left sternal border in the 4th and 5th interspaces /2/ Soft mid-systolic parasternal or pulmonic murmurs occur in atrial septal defect.

Contributors: (a) Kuo, Peter T., (b) Perloff, Joseph K.

References. [1] Wood, F. C Unpublished. [2] McKusick, V. A. 1958. Cardiovascular sound in health and disease. Williams and Wilkins, Baltimore. [3] Paulin, S., and E Mannheimer. 1957. Acta paediat., Upps. 46 438 [4] Levine, S. A., and W. P. Harvey. 1949. Clinical auscultation of the heart. W. B. Saunders, Philadelphia. [5] Friedman, S , W. A. Robie, and T. N. Harris. 1949. Pediatrics, Springf. 4 782. [6] Wolferth, C C Unpublished. [7] Ash, R 1948. Am. Heart J. 36:89. [8] Harris, T. N., and S. Friedman. 1952. Ibid. 43 707. [9] Harris, T. N. 1955. Ibid. 50 805. [10] Harris, T. N., S. Friedman, and C. F. Haub. 1949. Pediatrics, Springf. 3 845. [11] Messeloff, C. R. 1949. Am. J. M Sc. 217.17. [12] Lynxwiller, C. P., and J L Donahoe. 1955. South. M. J 48 164. [13] Stuckey, D 1957. Med. J. Australia 44.38. [14] Evans, W. 1947 Brit Heart J. 9 1. [15] Wells, B 1957 Ibid. 19.129.

76. PHYSIOLOGIC HEART SOUNDS AND MURMURS: MAN

	Heart Sound or Murmur	Probable Mechanism of Production	Frequency cps[1]	Duration sec	Phonocardiographic Registration			Audible Manifestation		Reference
					Linear[2]	Stethoscopic[3]	Logarithmic[4]	In Normal Subj.	Elicitation	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Atrial sound	Tensing of atrium or vibration of distended ventricles.	28-83	0.04-0.06	Yes	88%	21%	No	Pathologic conditions; occasionally in normal children.	B,1,2,C,D,3; E-G,4;H,I,5
2	1st heart sound	Muscular, valvular, and vascular factors.	33-111	0.06-0.16	Yes	Yes	Yes	Yes	Intensity varies with many physiologic and pathologic conditions.	B,1,6;C,D,7; E-G,4;H,I,5
3	1st component	Pre-isometric ventricular muscular and valvular factors.	35	0.03-0.06	Yes	Attenuated	No	No	None.	B-D,6;E-G,4; H,I,a
4	2nd component	Ventricular muscle tension and contraction, closure of atrioventricular valves.	34-39	0.03-0.05	Attenuated	Yes	Yes	Yes	Normally heard as a single sound, but sometimes is split due to asynchronous closure of atrioventricular valves under physiologic and pathologic conditions. Physiologically: mitral closure before tricuspid closure.	B-D,1,E-G,4; H,a;I,5
5	3rd component	Opening of semilunar valves, onset of ventricular ejection.	37-40	0.05-0.06	Attenuated	Yes	Yes	Yes		
6	4th component	Acceleration of blood in arterial vessels.	31-33	0.06-0.07	Yes	Attenuated	No	No	Pathologic conditions.	B-D,1;E-G,4; H,I,8
7	2nd heart sound	Valvular and vascular factors.	31-111	0.04-0.11	Yes	Yes	Yes	Yes	Intensity varies with many physiologic and pathologic conditions.	B,1;C,D,7;E-G,4;H,I,5
8	1st component	Relaxation of ventricles.			Yes	Attenuated	Attenuated	No	None.	B,E-G,4;H,I,9
9	2nd component	Closure of semilunar valves.			Yes	Yes	Yes	Yes	Sometimes is split under physiologic and pathologic conditions. Physiologically: aortic closure before pulmonic closure.	B,E-G,4;H,9, I,5,10
10	3rd component	Vibrations of arterial wall and blood column.			Yes	Attenuated	No	No	None.	B,E-G,4;H,I,9
11	4th component	Opening of atrioventricular valves.			Yes	Attenuated	No	No	Pathologic conditions.	B,E-G,4;H,I,5, 9
12	3rd heart sound (diastolic)	Distention of ventricles during period of rapid filling.	32-50	0.02-0.09	Yes	82%	30%	6-20%	In children and young adults: at apex, during inspiration in recumbent posture; pathologic conditions.	B,1;C,3;D-G, 4,H,11,12;I, 5
13	Systolic click	Extracardiac factors.		Short				0.6%	At apex and lower left sternal edge, varying with posture and respiration.	B,D,I,5,10;H, 12
14	Apical systolic murmur	Accelerated blood flow, acoustical characteristics of chest wall, respiratory factors.	120			58%	85%	2.3-9%	Acceleration of heart rate; deep expiration, recumbent posture, asthenia.	B,5,10,a,C,11; F,G,4;H,11-13;I,5,10,14

15	Precordial "vibratory" murmur	Vibration of cardiac tissue	128	0.114				Yes	In children and young adults; recumbent posture.	B,C,D,15,H,c, I,12,13
16	Pulmonary systolic murmur	Accelerated blood flow, position of pulmonary artery, acoustical characteristics of chest wall	Medium	Moderate				Yes	Acceleration of heart rate; deep expiration, recumbent posture.	B,10,a;C,D,a, H,c,I,10,14

/1/ Cycles per second. /2/ Records the heart sounds on the surface of the chest, as well as pulsations of the chest wall; actually an "apex cardiogram." /3/ Records the sound vibrations perceived by an observer of normal hearing, using an average acoustic bell stethoscope (light touch). /4/ Records the sound vibrations (audible heart sounds) perceived by an observer of normal hearing, using an average acoustic diaphragm stethoscope.

Contributors. (a) Porter, Reno R., (b) Kuo, Peter T., (c) McKusick, Victor A.

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77. CONGENITAL MALFORMATIONS OF THE HEART: MAN

Murmur: Parentheses indicate infrequent occurrence. QRS complex: RVH = right ventricular hypertrophy; RBBB = right bundle branch block; LVH = left ventricular hypertrophy; CVH = combined ventricular hypertrophy. Hemodynamics: RA = right atrium; RV = right ventricle; PA = pulmonary artery; AO = aorta or systemic artery, PF = pulmonary blood flow, CO = cardiac output. (0) = normal, (+) = increase, (-) = decrease.

	Cardiac Malformation	Murmur	Roentgenographic Findings			Electrocardiographic Findings		Hemodynamics								Prospect of Surgical Improvement
			Size and Shape of Heart	Pulmonary Conus	Pulmonary Vascularity	QRS Axis	QRS Complex	Pressure			O₂ Saturation				PF:CO Ratio[2]	
								RA[1]	RV	PA	RA	RV	PA	AO		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
	Cyanotic[3]															
1	Tetralogy of Fallot	Systolic[4] (Continuous)[5]	Boot shaped, usually not enlarged	Concave	-	Right	RVH	0	+	-	0	0	0	-	<1	Good
2	Pulmonary stenosis with atrial septal defect	Systolic	Right ventricle enlarged	Usually convex	-	Right	RVH	+	+	-	0	0	0	-	<1	Good
3	Transposition of great vessels with pulmonic stenosis	Systolic	Both ventricles enlarged; supracardiac vessels	Concave	-	Right	RVH	0	+	-	0	0	0	-	<1	None
4	Complete transposition of great vessels	Systolic (Diastolic)	Enlarged, supracardiac vessels narrow	Convex	+	Usually right	RVH or CVH	0	+	+	0	+	+	-	>1	None
5	Ebstein's anomaly, may be associated with a patent foramen ovale, an intact atrial septum, or an atrial septal defect	Systolic Diastolic None	Enlarged right atrium which is recessed into right ventricular cavity.	Convex	-	Right	RBBB (usually)	+	0 -[6]	0	0	0	0	-	<1	Poor
6	Tricuspid atresia	Systolic	Right ventricle diminutive	Concave	-	Left	LVH	+	0	0	0	0	0	-	<1	Fair to poor
7	Eisenmenger's complex	Systolic (Diastolic)	Both ventricles enlarged	Convex	+	Right	RVH or CVH	0	+	+	0	+	+	-	<1	Poor
8	Persistent truncus arteriosus	Systolic Diastolic None (Continuous)	Both ventricles enlarged	Concave	+ (may or may not)	Right	RVH or CVH	0	+	+	0	+	+	-	>1 (usually)	None
9	Patent ductus arteriosus with reversed shunt	Systolic Diastolic[7] None (Continuous)	Both ventricles enlarged	Convex	+	Right	CVH	0	+	+	0	0	+	-	>1	Poor
10	Complete anomalous pulmonary venous drainage	Systolic Diastolic (Continuous)	Characteristic "figure eight" silhouette	Convex	+	Right	RVH	0	+	+	+	+	+	-	>1	Poor
	Acyanotic															
11	Isolated pulmonary stenosis	Systolic	Right ventricle enlarged	Concave or convex	-	Right	RVH	+	+	-	0	0	0	0	<1	Good
12	Atrial septal defect, secundum type	Systolic (Diastolic)	Right ventricle enlarged	Convex[8]	+	Right	RBBB or RVH	0	0	0	+	+	+	0	>1	Good

13	Atrial septal defect, *ostium primum type*	Systolic Diastolic	*Both ventricles enlarged*	*Convex*	+	Right or left	CVH	0	+	+	+	+	+	-	>1	Fair to poor
	Ventricular septal defect															
14	Small	*Systolic*	*Normal*	*Convex*	0	0	0	0	0	0	0	+	+	0	>1	Good
15	Large	Systolic None (Diastolic)	Both ventricles enlarged	*Convex*	+	Right	RVH, RBBB or CVH	0	+	+	0	+	+	0	>1	Fair
16	*Patent ductus arteriosus*	Continuous (*Diastolic*)	Normal, or left ventricle *enlarged*	Convex	+	Left	0 *or* LVH	0	0	0	0	0	+	0	>1	Good

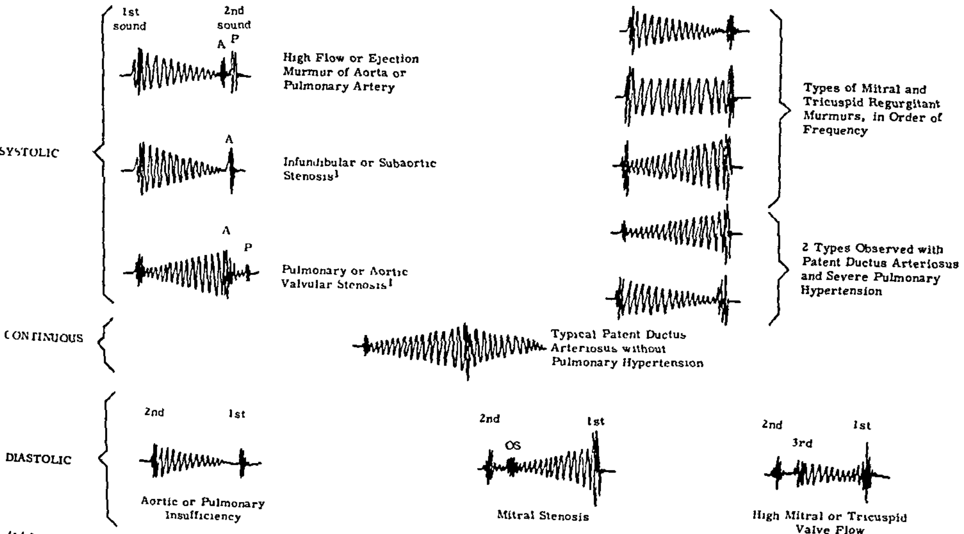
/1/ Indicated increase in pressure refers to height of A wave of atrial pulse; *mean pressure* is usually normal. /2/ Does not take into account collateral circulation to *lungs when pulmonary stenosis is present*. /3/ Only the more common pathologic combinations are listed. The hemodynamics in each complicated anomaly (*determined by relative severity of component abnormalities*) vary widely, and are *discussed* in detail in the references. /4/ Across the pulmonary valve. /5/ Continuous *murmur originates in bronchial collaterals* and is generally *confined* to individuals with pulmonary atresia. /6/ Ventricle *is functionally* divided into 2 chambers with different pressures /7/ Of pulmonary insufficiency only. /8/ Normal when shunt is small.

Contributors: (a) Witham, A Calhoun, (b) *Glenn*, William W. L., (c) Perloff, Joseph K.

References: [1] Kjellberg, S. R., E. *Mannheimer*, O. Rudhe, and B. *Jonsson*. 1955. Diagnosis of congenital heart disease. Year Book Publishers, Chicago. [2] Brown, J. W. 1950. Congenital *heart disease*. Ed. 2. Staples Press, London. [3] Nadas, A. 1957. Pediatric cardiology. W. B. Saunders, *Philadelphia*. [4] Witham, A. C., and R. Ellison. 1957. Am. J. Med. 22:593. [5] Gould, S. E. 1953. Pathology of the heart. C. C. Thomas, *Springfield, Ill.* [6] McKusick, V. A. 1958. Cardiovascular sound in health and disease. Williams and Wilkins, Baltimore. [7] Bing, R. J., T. A. *Lombardo*, L. M. *Burgeron*, M. Taeschler, and S. Tulug. 1952. Ann. Int. M. 37 664. [8] Cournand, A., J. S. Baldwin, and A. Himmelstein. 1949. Cardiac catheterization in congenital heart disease. Commonwealth Fund, New York.

78 HEART MURMURS WITH CHARACTERISTIC PHONOCARDIOGRAPHIC CONFIGURATIONS MAN

Only those murmurs with typical configuration are presented; schematic drawings simulate shape but not frequency. Abbreviations: A = aortic valve closure, P = pulmonic valve closure, OS = opening snap of mitral stenosis, 1st = 1st heart sound, 2nd = 2nd heart sound, 3rd = 3rd heart sound (rapid filling).

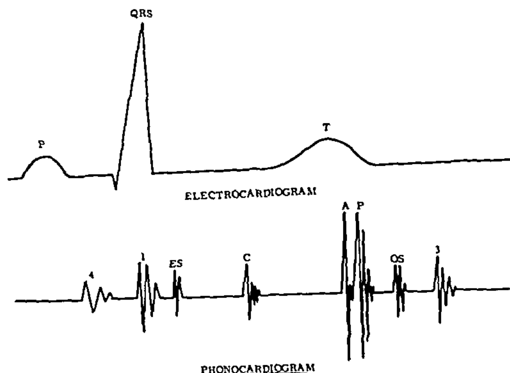


/1/ Labels for semilunar valve closure indicate pulmonary circuit obstruction and should be reversed for aortic lesions.

Contributor: Witham, A. Calhoun

References: [1] Levine, S. A., and W. P. Harvey. 1949. Clinical auscultation of the heart. W. B. Saunders, Philadelphia. [2] Wells, B. G., M. B. Rappaport, and H. B. Sprague. 1949. Am. Heart J. 37:586. [3] Wells, B. G. 1952. Brit. Heart J. 14:261. [4] Ongley, P. A., H. B. Sprague, and M. B. Rappaport. 1955. N. England J. M. 253:1049. [5] Brigden, W., and A. Leatham. 1953. Brit. Heart J. 15:55. [6] Kjellberg, S. R., E. Mannheimer, O. Rudhe, and B. Jonsson. 1955. Diagnosis of congenital heart disease. Year Book Publishers, Chicago. [7] McKusick, V. A. 1958. Cardiovascular sound in health and disease. Williams and Wilkins, Baltimore.

79. RELATION OF NORMAL AND PATHOLOGIC HEART SOUNDS TO THE CARDIAC CYCLE, MAN

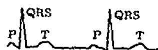


	Sound (A)	Appearance (B)	Cause (C)	Remarks (D)
1	4	Near end of P wave	Atrial contraction	Usually observed with atrial hypertrophy.
2	1	End of QRS	Mainly closure of atrio-ventricular valves	Normal heart sound, may be split. May be delayed and accentuated in mitral stenosis.
3	ES	0.04-0.10 sec after 1st sound onset	Sudden distension of aorta or pulmonary artery ("ejection sound").	Observed with dilatation of either the aorta or pulmonary artery. May be delayed 4th component of 1st sound. Pulmonic ejection sound often selectively decreases with inspiration and increases with expiration.
4	C	Highly variable	Uncertain, extra-cardiac.	Usually changes with posture and respiration. Often observed in individuals with history of pleuroperi-cardial disease
5	A	Near end of T wave	Closure of aortic valve	Normal part of 2nd sound. Intensity varies with pressure in aorta. Delayed sound in left bundle branch block, valvular stenosis.
6	P	Near end of T wave	Closure of pulmonic valve	Normal part of 2nd sound. Intensity varies with pressure in pulmonary artery. Delayed sound in right bundle branch block, valvular stenosis, and high right ven-tricular stroke volume.
7	OS	0.03-0.14 sec after 2nd sound	Opening snap of mitral or tricuspid valve	Observed with stenosis, either valve. Time of appear-ance after 2nd sound varies inversely with respective atrial pressures
8	3	0.16-0.24 sec after 2nd sound onset	Rapid distension of either ventricle	Normal heart sound. Accentuated in heart failure, rapid ventricular inflow. With rapid heart rate, sounds 4 and 3 may occur simultaneously ("summation gallop rhythm").

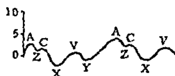
Contributors: (a) Witham, A. Calhoun, (b) Perloff, Joseph K.

References: [1] Leatham, A., and L. Vogelpoel. 1954. Brit. Heart J. 16:21. [2] Rappaport, E., and H. B. Sprague. 1942. Am. Heart J. 23:591. [3] Mounsey, P. 1953. Brit. Heart J. 15:135. [4] Levine, S. A., and W. P. Harvey. 1949. Clinical auscultation of the heart. W. B. Saunders, Philadelphia. [5] Weil, B. G. 1954. Brit. Heart J. 16:261. [6] McKusick, V. A. 1958. Cardiovascular sound in health and disease. Williams and Wilkins, Baltimore.

Part I: INTRACARDIAC PULSE



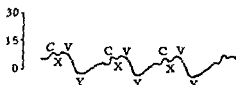
Normal ECG



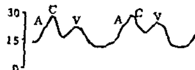
Normal Right Atrial Configuration



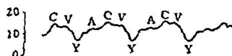
Giant A wave, Right Atrial Configuration
in Right Ventricular Hypertension or Tricuspid Stenosis



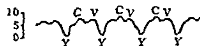
Right Atrial Tracing in Fibrillation
(Inconspicuous X descent, no A wave)



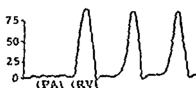
Left Atrial Configuration *in* Mitral Stenosis



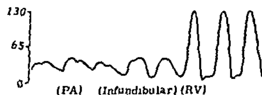
Right Atrial Tracing *in* Tricuspid Insufficiency
(High systolic plateau followed by deep Y descent)



Early Diastolic Collapse, Right Atrial Configuration
in Constrictive Peri- or Endocarditis, Amyloidosis



In Valvular Pulmonary Stenosis



In Infundibular Pulmonary Stenosis

(Continuous recording, withdrawal of catheter, pulmonary artery (PA) to right ventricle (RV))



Right Ventricular Pulse in *Constrictive Pericarditis*
(Accentuated early *diastolic dip, high diastolic plateau*)

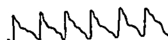
Contributor: Witham, A. Calhoun

References: [1] Broadbent, W. H. 1890. *The pulse.* Cassell, London. [2] MacKenzie, J. 1902. The study of the pulse. Young J. Pentland, Edinburgh and London. [3] Marey, E. J. 1878. La methode graphique. G. Masson, Paris. [4] Wood, P. 1956. Diseases of the heart and circulation. Ed 2, rev. J. B. Lippincott, Philadelphia.

Part II ARTERIAL RADIAL PULSE



Normal Radial Pulse



Corrigan Pulse
In Aortic Insufficiency
(Rapid upstroke and diastolic collapse)



Plateau Pulse
In Aortic Stenosis
(Slow rise and fall, low pulse pressure)



Pulsus Bisferiens
In Combined Aortic Stenosis and Insufficiency
(Double systolic peak)



Pulsus Alternans
In Myocardial Insufficiency
(Alternating weak and strong beats)



Anacrotic Pulse



Dicrotic Pulse
In Low Peripheral Resistance
(Increased dicrotic wave)

Contributor. Witham, A Calhoun

References [1] Broadbent, W H 1890. The pulse. Cassell, London. [2] MacKenzie, J. 1902 The study of the pulse Young J Pentland, Edinburgh and London. [3] Marey, E J 1878 La methode graphique. G. Masson, Paris [4] Vierordt, K. 1855. Die Lehre von Arterienpuls in Gesünden und Kranken Zuständen. F. Vieweg, Brunswick [5] Wood, P 1956 Diseases of the heart and circulation Ed 2, rev. J. B. Lippincott, Philadelphia.

81. EFFECT OF PREGNANCY ON CIRCULATORY FUNCTION: MAN

Values in parentheses are ranges, estimate "b" (cf. Introduction).

	Variable	Method	No. of Subjects	Non-pregnant	Lunar Month of Pregnancy: Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	First Month Post-partum	Re[illegible]
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	
1	Heart rate, beats/min	Pulse	68	68		78			78			82			
2			6				83	84	85	87	89	85	83	77	
3	Cardiac output, L/min	Catheterization	46	5.5				6.49	6.57	6.96 (4.6-9.3)	6.59 (4.4-8.7)	5.75 (4.3-7.2)	5.53 (4.1-7.0)		
4		Dye dilution	31	6.3				6.4	5.5	8.3	6.6	5.7	5.4	5.6	4
5		Acetylene	6				3 8	3.6	4.8	4.6	5.1	5.0	4.2		2
6	Cardiac index, L/min/sq m	Direct Fick	46	3.1 (2.0-3.8)				4.0 (3 3-4.9)	4 2 (3.1-4.9)	4.3 (2.8-5.7)	3.9 (2.6-5.2)	3.6 (2.5-4.7)	3.4 (2.5-4.3)		3
7	Arterial pressure, mm Hg	Sphygmo-manometer	68	121/75 (96/58-138/98)		115/70 (104/64-121/74)			106/70 (94/60-134/68)			114/72 (82/54-130/84)			1
8			6					110/66	113/66	117/66	115/64	109/70	115/72	114/80	2
9	Venous pressure, cm H_2O Femoral	Water manometer	158	11.4 (4-18)	9.1 (2-16)		14.0 (0-28)	14.6 (6-21)	17.8 (12-24)	21.0 (16-26)	22.3 (17-27)	21.3 (13-29)	24.4 (15-33)	9.0 (4-14)	5
10	Antecubital	Water manometer	158	7.9 (5-11)	7.9 (4-12)		8.1 (1-15)	7.6 (1-14)	8.9 (4-14)	10.8 (5-17)	7.2 (2-12)	7.0 (1-13)	7.6 (2-13)	7.6 (3-12)	5
11	Right atrial pressure, mm Hg	Catheterization	46	<5				(0-5)	(0-5)	(2-7)	(0-7)	(0-6)	(0-4)		3
12	Pulmonary artery mean pressure, mm Hg	Catheterization	42					12.0	10.0	11.0 (4.5-17.5)	11.7 (7.0-16.4)	11.1 (5-17)	11.0 (5.5-16.5)		3
13	Right ventricular pressure, mm Hg	Catheterization	46	<30/5					(15/0-21/5)	(15/2-27/7)	(14/0-26/7)	(14/1-23/10)	(11/0-22/4)		3
14	Total peripheral resistance, dynes sec/cm5	Direct Fick, catheterization, calculation	33	1200				877	1095	1009 (570-1450)	1078 (525-1630)	1138 (590-1690)	1244 (940-1550)		3
15	Left ventricular work, kg-m/min/sq m	Direct Fick, catheterization, calculation	33					4.5	4.9	4 6 (3.5-5.8)	4.6 (2.3-7.0)	4.2 (1.5-6.9)	4.2 (2.6-4.8)		6
16	Blood volume, L	P32-labelled RBC	157	3.7 (2.8-4 6)	3 4 (2 2-4 6)	3.6 (2 6-4.6)	3.9 (3.1-4.7)	4.2 (3 0-5.4)	4.5 (3.6-5.4)	4.4 (2.8-6.0)	4.4 (3.4-5.4)	5.0 (3.6-6.4)	5.2 (3.8-6.6)	3.7 (2.6-4.8)	7
17		Evans' blue + Fe55 labelled RBC	12	4.2	3.9	4.3	4.9	5 0	5.4	5.8	5.9	6.1	5.7	4.3	8
18	Plasma volume, L	P32-labelled RBC	157	2.1 (1.5-2.7)	2.3 (1 6-3.0)	2 3 (1.7-2.9)	2.4 (1 7-3.1)	2.7 (1.9-3.5)	2.8 (2.3-3.3)	2.9 (2.8-4 0)	2.9 (2.5-3.3)	3.1 (2.2-4 0)	3.3 (2.6-4.1)	2.3 (1.7-2.9)	7
19		Evans' blue	12	2.9	2.8	3.0		3.3	3.8	4.0		3 8		2.9	8
20			14			2.8	2 7	3.0	3.3	3 7	3.7	4.0	3.8	2.9	9

21	RBC volume, L	P32- or Fe55-labelled RBC	257	1.6 (1.2-2.0)	1.4 (0.8-2.0)	1.3 (1.0-1.6)	1.4 (1.1-1.7)	1.4 (1.0-1.8)	1.6 (1.2-2.0)	1.5 (1.0-2.0)	1.5 (0.9-2.1)	1.6 (1.3-1.9)	1.8 (1.2-2.4)	1.4 (1.1-1.7)	7
22			12	1.2	1.2	1.4		1.4	1.5	1.6		1.7		1.5	8
23		Evans' blue + hematocrit	14			1.6	1.7	1.8	1.9	2.0	2.1	2.0	2.0	1.8	9
24	Blood flow Uterine, ml/100 g/min	Nitrous oxide	11										15 (12.2-18.5)	9	10
25			14										12.8 (3-23)		11
26	Effective renal, ml/min/ 1.73 sq m	p-Amino-hippurate clearance	11	950			1314 (870-1760)			1217 (960-1480)	1143 (530-1750)	1119 (480-1760)	943 (490-1400)	760 (330-1190)	12
27	Hepatic, ml/min/ 1.73 sq m	Bromsulphalein clearance	15	1554 (1164-1944)		1803[1]		1500[2]	1650[3]	1556[3]		1075[2]	1423 (770-2070)		13
28	Cerebral, ml/100 g/min	Nitrous oxide	105	54 (32-76)									54 (34-74)		14
29	Forearm, ml/100 ml/min	Venous occlusion	8	2.06				3.2				3.1	3.9	2.6	15
30		Plethysmo-kymography	58	4.56									8.73		16
31	Hand, ml/100 ml/min	Venous occlusion	58	1.0		1.5		7.5		7.5	10.0	10.0	14.5		15
32	Finger, ml/sq cm/min	Calorimetric	16	0.20 (0.08-0.32)									0.29 (0.15-0.43)		17
33	Leg, ml/100 ml/min	Plethysmo-kymography	58	1.87									3.18		16
34	Apparent viscosity of whole blood relative to water	Ostwald viscosimeter	362	4.61	4.20	4.19	4.11	3.92	3.84	3.95	4.32	4.16	4.49	4.61	18

/1/ 4 subjects /2/ 1 subject. /3/ 2 subjects.

Contributors (a) Assali, N. S., R. Jensen, and S. Larke, (b) Chesley, Leon C.

References: [1] Hamilton, H. F. H. 1949. J. Obst. Gyn. Brit. Empire 56:548. [2] Burwell, C. S., et al. 1938. Arch. Int. M. 62:979. [3] Bader, R., et al 1955. J. Clin. Invest. 34:1524. [4] Adams, J. Q 1954. Ibid. 67:741. [5] McLennan, C. E. 1943. Am. J. Obst. 45:568. [6] Rose, B. J., M. E. Bader, R. A. Bader, and E. Brauwald. 1956. Ibid. 72:233. [7] Berlin, N. I., et al. 1953. Surg. Gyn. Obst. 97:173. [8] Caton, W. J., et al. 1951. Am. J. Obst. 61:1207. [9] Tysoe, F. W., and L. Lowenstein. 1950. Ibid. 60.1187. [10] Assali, N. S., et al. 1953. Ibid. 66:248. [11] Metcalfe, J., et al. 1955. J. Clin. Invest. 34:1632. [12] Sims, E. A. H., and K. E. Krantz. 1958. Ibid. 37:1764. [13] Munnell, E. W., and H. C. Taylor, Jr. 1947. Ibid. 26:952. [14] McCall, M. L. 1953. Am. J. Obst. 66:1015. [15] Burt, C. C. 1950. Edinburgh M. J. 57:18. [16] Herbert, C. M., E. A. Banner, and K. G. Wakim. 1958. Am. J. Obst. 76:742. [17] Mendlowitz, M., A. Altchek, and N. Naftchi. 1958. Ibid. 76:473. [18] Hamilton, H. F. H. 1950. J. Obst. Gyn. Brit. Empire 57:330.

82. HEMODYNAMIC EFFECTS OF HYPOXIA (LOW O_2)

Part I. HEART SIZE: MAMMALS

	Animal (A)	Condition Producing Hypoxia (B)	Measurement (C)	Effect (D)	Reference (E)
1	Man	12,000 ft altitude, 3 hr daily for 4 wk		No change in size.	1
2		13,000 and 23,000 ft in altitude chamber	X-ray examination	No definite relationship between altitude changes and changes in X-ray size of heart.	2
3		O_2 mixture equivalent to that at 18,000-20,000 ft altitude	Electrokymography	No change in size.	3
4		Gradually increasing daily exposures up to 27,000 ft over a total of 35 da	X-ray examination	Decrease in size.	4
5		Up to 30,800 ft altitude	X-ray examination	Changes in X-ray contour not consistent (increases and decreases).	5
6		18,000 ft altitude	X-ray kymography	Increase in size, systolic volume from 149 sq cm at sea level to 160 sq cm, and diastolic volume from 157 sq cm at sea level to 171 sq cm.	6
7		21,300 ft altitude	X-ray kymography	Decrease from heart size at 18,000 ft (line 6).	6
8	Flying personnel	Intermittent exposure to altitude for 1 yr or longer	X-ray examination	Increase in size; muscle hypertrophy.	7
9		Intermittent exposure to altitude for 1-10 yr	X-ray examination	Increase in size.	8
10		16,400-19,700 ft altitude with supplementary O_2	X-ray examination	No change in size.	9
11		16,400-19,700 ft altitude without supplementary O_2	X-ray examination	Increased right heart.	9
12	Residents	10,000-15,000 ft altitude		Increase in size, transverse diameter 15% above normal, frontal area 16.3% above normal; no further enlargement with age.	10
13		15,000 ft altitude		Increase in size; transverse diameter increased in 50-65% of healthy adults; abnormal diameter of aortic pedicle and prominence of pulmonary conus.	11
14		High altitude		Increase in size	12
15	Cat	Reduced inspiratory O_2 content		Increase in size; most drastic in slight hypoxia.	13
16	Dog	100% nitrogen for 2-3.5 min		Increase in size, dilated approximately 75 sec after start of inhalation.	14
17		10% O_2-gas mixture		Increase in size; diastolic volume increased independently of change in venous pressure.	15
18	Rabbit	Acute exposure following rapid ascent to 31,000-36,000 ft altitude	X-ray kymography	Increase in size; beginning at 14,710 ft, all 4 sectors of heart dilated, especially laterally.	16
19		Several hr at 32,500 ft after rapid ascent	X-ray kymography	Initially dilated heart (line 18) became smaller.	17
20		Several hr at 32,500 ft after slow ascent	X-ray kymography	Usually no change, decrease in some cases.	17

Contributor: Marbarger, John P.

References: [1] Clinton, M., Jr., G. W. Thorn, and V. D. Davenport. 1946. Bull. Johns Hopkins Hosp. 79:70. [2] Meister, W., and H. Derlich. 1938. Luftfahrtmedizin 3:314. [3] Keys, A., J. P. Stapp, and A. Violante. 1943. Am. J. Physiol. 138:763. [4] Graybiel, A., J. L. Patterson, Jr., and C. S. Houston. 1948. Proj. NM 001-013, Rep. 6. U. S. Naval School of Aviation Medicine, Pensacola, Fla. [5] Spycher, C. 1931. Arbeitsphysiologie 4:390. [6] Heddäus, C. 1940. Luftfahrtmed. Abh. 3:20. [7] Schaare, U. 1938. Luftfahrtmedizin 3:104. [8] Hurtado, A., et al. 1947. J. Aviat. M. 18:406. [9] Pescador, L. 1941. Rev. clín. españ. 2:449. [10] Kerwin, A. J. 1944. Am. Heart J. 28:69. [11] Miranda, A., and A. Rotta. 1944. An. Fac. med. Lima 28:69. [12] Monge, C. 1943. Physiol. Rev. 23:166. [13] Takenchi, K. 1925. J. Physiol., Lond. 60:208. [14] Feldman, M., Jr., et al. 1948. Am. J. Physiol. 154:391. [15] Strughold, H. 1930. Ibid. 94:641. [16] Weltz, G. A., et al. 1938. Luftfahrtmedizin 2:27. [17] Weltz, G. A., and H. Kottenhoff. 1938. Ibid. 2:33.

Part II ARTERIAL, VENOUS, AND PULSE PRESSURES MAN

Blood pressure values obtained by arterial and venous catheterization, except for lines 1 and 3.

	Pressure	Condition Producing Hypoxia	Blood Pressure after Exposure for, 0 min mm Hg	5 min mm Hg	5 min % Change	10 min mm Hg	10 min % Change	15 min mm Hg	15 min % Change	20 min mm Hg	20 min % Change	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
1	Systolic arterial	10% O_2	129	135	+4.7	137	+6.2	136	+5.4	135	+4.7	1
2		18,000 ft alt	123.7	123.0	-0.6	121.9	-1.5	114.1	-7.8	117.3	-5.2	2
3	Diastolic arterial	10% O_2	81	83	+2.5	82	+1.3	81	0	78	-3.7	1
4		18,000 ft alt	69.3	67.7	-2.3	66.3	-4.3	59.0	-14.9	61.4	-11.4	2
5	Pulse pressure	10% O_2	48	52	+8.3	55	+14.6	55	+14.6	57	+18.7	1
6		18,000 ft alt	54.6	55.3	+1.2	54.4	-0.3	55.1	+1.0	55.9	+2.4	2
7	Arterial, mean	18,000 ft alt.	91.2	89.4	-2.0	87.5	-4.0	78.2	-14.3	80.6	-11.6	2
8	Venous, mean	18,000 ft alt	48	51	+6.2	53	+10.4	57	+18.7	52	+8.3	2

Contributor: Marbarger, John P

References: [1] Mathers, J. A. L., and R. L. Levy. 1950. Circulation, N. Y 1:426. [2] Marbarger, J. P., et al. 1952. Proj. 21-23-019 (1). USAF School of Aviation Medicine, Randolph Field, Tex.

Part III: SYSTEMIC, PULMONARY, AND RIGHT VENTRICULAR PRESSURES: MAN

	Pressure	Condition Producing Hypoxia: O_2 Content %	Condition Producing Hypoxia: Altitude Equivalent ft	Exposure Time min	Blood Pressure Changes, mm Hg: Systolic	Diastolic	Pulse	Arterial (Mean)	Venous (Mean)	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
				Simulated Altitude						
1	Systemic	14.4	10,000	10	-0.1	-0.4	+0.3	-1.4	-4.0	1
2		13.4-10.4	16,000-18,000	30	0	-10.0	+10.0			2
3		10.4	18,000	10	-1.8	-3.0	-0.2	+3.7	+1.0	1
4		10.4	18,000	20	-6.4	-7.9	+1.3	-10.6	+0.2	1
				Oxygen Mixture						
5	Systemic	10.0	19,000	10	+8.0	+1.0	+7.0			3
6		10.0	19,000	20	+6.0	-3.0	+9.0			3
7		10.0	19,000	10	-4.0	-7.0	+3.0	-5.0		4
8		10.0	19,000	10	+7.0	+1.0	+6.0	+3.0		5
9	Pulmonary	10.0	19,000	10	+7.0	+3.0		+5.0		4
10		10.0	19,000	10	+13.2	+7.0		+9.9		5
11	Right ventricular	10.0	19,000	10	+13.0	+2.8			+6.1	5

Contributor: Marbarger, John P.

References: [1] Marbarger, J. P., et al. 1952. Proj. 21-23-019 (1). USAF School of Aviation Medicine, Randolph Field, Tex. [2] Starr, I., and M. McMichael. 1948. J. Appl. Physiol. 1:430. [3] Mathers, J. A. L., and R. L. Levy. 1950. Circulation, N. Y. 1:426. [4] Doyle, J. T., et al. 1951. Proj. NM 001 050.01.04. U. S. Naval School of Aviation Medicine, Pensacola, Fla. [5] Motley, H. L., et al. 1947. Am. J. Physiol. 150 315.

82. HEMODYNAMIC EFFECTS OF HYPOXIA (LOW O_2)

Part I· HEART SIZE· MAMMALS

	Animal (A)	Condition Producing Hypoxia (B)	Measurement (C)	Effect (D)	Reference (E)
1	Man	12,000 ft altitude, 3 hr daily for 4 wk		No change in size.	1
2		13,000 and 23,000 ft in altitude chamber	X-ray examination	No definite relationship between altitude changes and changes in X-ray size of heart.	2
3		O_2 mixture equivalent to that at 18,000-20,000 ft altitude	Electrokymography	No change in size.	3
4		Gradually increasing daily exposures up to 27,000 ft over a total of 35 da	X-ray examination	Decrease in size.	4
5		Up to 30,800 ft altitude	X-ray examination	Changes in X-ray contour not consistent (increases and decreases).	5
6		18,000 ft altitude	X-ray kymography	Increase in size, systolic volume from 149 sq cm at sea level to 160 sq cm, and diastolic volume from 157 sq cm at sea level to 171 sq cm.	6
7		21,300 ft altitude	X-ray kymography	Decrease from heart size at 18,000 ft (line 6).	6
8	Flying personnel	Intermittent exposure to altitude for 1 yr or longer	X-ray examination	Increase in size; muscle hypertrophy.	7
9		Intermittent exposure to altitude for 1-10 yr	X-ray examination	Increase in size.	8
10		16,400-19,700 ft altitude with supplementary O_2	X-ray examination	No change in size.	9
11		16,400-19,700 ft altitude without supplementary O_2	X-ray examination	Increased right heart.	9
12	Residents	10,000-15,000 ft altitude		Increase in size, transverse diameter 15% above normal, frontal area 16.3% above normal; no further enlargement with age.	10
13		15,000 ft altitude		Increase in size; transverse diameter increased in 50-65% of healthy adults, abnormal diameter of aortic pedicle and prominence of pulmonary conus.	11
14		High altitude		Increase in size.	12
15	Cat	Reduced inspiratory O_2 content		Increase in size; most drastic in slight hypoxia.	13
16	Dog	100% nitrogen for 2-3.5 min		Increase in size; dilated approximately 75 sec after start of inhalation.	14
17		10% O_2-gas mixture		Increase in size, diastolic volume increased independently of change in venous pressure.	15
18	Rabbit	Acute exposure following rapid ascent to 31,000-36,000 ft altitude	X-ray kymography	Increase in size, beginning at 14,710 ft, all 4 sectors of heart dilated, especially laterally.	16
19		Several hr at 32,500 ft after rapid ascent	X-ray kymography	Initially dilated heart (line 18) became smaller.	17
20		Several hr at 32,500 ft after slow ascent	X-ray kymography	Usually no change, decrease in some cases.	17

Contributor: Marbarger, John P.

References. [1] Clinton, M., Jr., G. W. Thorn, and V. D. Davenport. 1946 Bull. Johns Hopkins Hosp. 79:70. [2] Meister, W., and H. Derlich. 1938. Luftfahrtmedizin 3.314. [3] Keys, A., J. P. Stapp, and A. Violante. 1943 Am. J Physiol. 138:763. [4] Graybiel, A., J. L. Patterson, Jr., and C. S. Houston 1948. Proj. NM 001-013, Rep. 6. U. S. Naval School of Aviation Medicine, Pensacola, Fla. [5] Spycher, C. 1931. Arbeitsphysiologie 4.390. [6] Heddäus, C. 1940. Luftfahrtmed. Abh. 3:20. [7] Schaare, U 1938. Luftfahrtmedizin 3:104. [8] Hurtado, A., et al. 1947. J. Aviat. M. 18:406. [9] Pescador, L. 1941 Rev clín españ. 2:449. [10] Kerwin, A J. 1944. Am. Heart J. 28 69. [11] Miranda, A., and A. Rotta. 1944. An. Fac. med. Lima 28 69 [12] Monge, C. 1943 Physiol. Rev. 23:166. [13] Takenchi, K. 1925. J. Physiol., Lond. 60:208. [14] Feldman, M, Jr., et al. 1948. Am. J. Physiol. 154.391 [15] Strughold, H. 1930. Ibid. 94:641. [16] Weltz, G. A., et al. 1938. Luftfahrtmedizin 2 27. [17] Weltz, G. A., and H. Kottenhoff. 1938. Ibid. 2 33.

	Body Part or Region (A)	Condition Producing Hypoxia (B)	Effect (C)	Reference (D)
			Man	
1	Finger	6.4% O_2-gas mixture	Increase at first, decrease later.	1
2		7% O_2-gas mixture	Effect varies.	2
3		10% O_2-gas mixture	30% decrease	3
4	Hand	10% O_2-gas mixture for 10-27 min	Decrease.	4
5	Forearm and leg	10% O_2-gas mixture for 10-27 min	Increase.	4
6	Ear	6.4% O_2-gas mixture	Increase in peripheral blood, independent of blood pressure.	1
7	Scalp region	7% O_2-gas mixture	Increase in peripheral blood with increased skin temperature of ear.	2
8	Capillaries	Altitude of 5200 ft	Decrease in peripheral blood. Mean resistance increased 25 mm Hg; return to sea level values during continued stay at 5200 ft.	5
9		High altitudes (acclimatized residents)	Dilated.	6
10	Splanchnic region	Unspecified	Decreased in intestinal vessels	7
11			Increased in hepatic artery.	7
12		Unspecified	Circulation changed locally in proportion to arterial blood pressure, especially in splanchnic region	8
			Dog	
13	Skin	Breathing "normal" O_2 from demand system at 35,000 ft	Decrease in peripheral blood indicated by significantly reduced temperature.	9
14	Skin and muscle	O_2-gas mixture	Initially strong increase.	10
15	Internal carotid artery	O_2-N_2 mixture	Transient increase.	11
16	Kidney	Unspecified	Decrease in peripheral blood, independent of blood pressure.	12

Contributor: Marbarger, John P.

References: [1] Matthes, K., and K. Schlaudraff. 1944. Luftfahrtmedizin 8:161. [2] Matthes, K., and R. Falk. 1941. Verh. deut. Ges. Kreislaufforsch. 14:109. [3] Steele, J. M. 1942. Nat. Res. Counc. Proj. OEMcmr 130 (Rep. 7). [4] Abramson, D. I., H. Landt, and J. E. Benjamin. 1943. Arch. Int. M. 71:583. [5] Schmid, A. 1949. Helvet. physiol. pharm. acta 7:267. [6] Monge, C. 1943. Physiol. Rev. 23:166. [7] Rein, H. 1943. Verh. deut. Ges. Kreislaufforsch. 246:880. [8] Jensen, K., W. Kratz, and W. Schoedel. 1940. Luftfahrtmedizin 5:40. [9] Lipin, J. L., and W. V. Whitehorn. 1951. J. Aviat. M. 22:278. [10] Noell, W., and M. Schneider. 1941. Luftfahrtmedizin 5:234. [11] Benfinger, T., E. Opitz, and W. Schoedel. 1938. Ibid. 3:46. [12] Kreienberg, W., L. Prokop, and T. Schiller. 1949. Pflügers Arch. 251:675.

82. HEMODYNAMIC EFFECTS OF HYPOXIA (LOW O_2) (Continued)

Part IV ARTERIAL BLOOD PRESSURE DURING PROGRESSIVE ADAPTATION TO ALTITUDE: MAN

Values in parentheses are ranges, estimate "b" (cf. Introduction).

	Altitude ft	Systolic Blood Pressure			Diastolic Blood Pressure			Mean Blood Pressure		
		Value mm Hg	Change		Value mm Hg	Change		Value mm Hg	Change	
			mm Hg	%		mm Hg	%		mm Hg	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(
1	Sea level (control)	112.50(92.76-132.24)			69.16(58 34-79.98)			90.83(76.43-105.23)		
2	12,140	118.33(98.53-138.13)	+5.83	+5.2	84.16(73.28-95.04)	+15.0	+21.7	101.25(88.75-113.75)	+10.42	+1
3	13,120	125.00(98.60-151.40)	+12.5	+11.1	88.33(77.19-99.47)	+19.17	+27.7	107.08(87.58-126.58)	+16.25	+1
4	19,360	130.00(105.40-154.60)	+17.5	+15.6	93.33(74.43-112.23)	+24.17	+35.0	111.66(90.46-132.86)	+20.83	+2

Contributor: Marbarger, John P.

Reference: Hartman, H., G. Hepp, and U. C. Luft. 1941. Luftfahrtmedizin 6:1. (Nanga Parbat expedition).

PART V· PULSE RATE CHANGE, IN PERCENT OF GROUND LEVEL VALUE, DURING PROGRESSIVE EXPOSURE: MAN

Pulse rate index at ground level = 100.

	Simulated Altitude ft	O_2 Content %	Pulse Rate Change, in % of Ground Level Value, after Exposure for:					
			10 min	20 min	30 min	40 min	50 min	60 min
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	12,000	13.3	113	115	113	106	104	99
2	16,000	11.4	111	110	103	103	101	105
3	18,000	10.5	107	109	108	111	108	104
4	20,000	9.6	124	112	117	107		
5	22,000	8.8	131	126	124			

Contributor. Marbarger, John P

Reference· Rahn, H , and A. B. Otis. 1947. Am. J. Physiol. 150:202.

Part VI: PULSE RATE CHANGE DURING PROGRESSIVE EXPOSURE: MAN

	Condition Producing Hypoxia	O_2 Content %	% Change in Pulse Rate after Exposure for:					Reference
			5 min	10 min	15 min	20 min	33 min	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	18,000 ft simulated altitude	10.4	25	30	30	28		1
2	Gas mixture	10.0	17	20	21	20		2
3	Gas mixture	10.5	14	31	31	32	33	3

Contributor· Marbarger, John P.

References (1) Marbarger, J. P., et al. 1952. Proj. 21-23-019 (1). USAF School of Aviation Medicine, Randolph Field, Tex. [2] Mathers, J. A. L., and R. L. Levy. 1950. Circulation, N. Y 1 426. (3) Schaefer, K. E., and H. J. Alois. 1951. Bur. Med. Proj. NM 002 015.03.02. U. S. Naval Marine Base, New London, Conn.

Part X AMPLITUDES OF THE ELECTROCARDIOGRAM, MAN

For additional information on the *ECG*, see pages 137-145.

	Wave (A)	Condition Producing Hypoxia (B)	Effect (C)	Reference (D)
1	P	O_2-gas mixture (arterial O_2 saturation = 95-70%)[1]	levation for P_1 and P_2.	1
2		Short exposures at simulated altitude of 25,000 and 35,000 ft	ances, increase from 0.05-0.15 mv.	2
3		Simulated altitude of 19,685 ft	nce from sea level = +0.25 mm (sitting).	3
4		Simulated altitude of 23,000-26,250 ft	ve increased.	4
5		7% O_2-gas mixture	d decreased without consistency.	5
6		Continuous exposure to low O_2[2]	ave	6
7	QRS complex	Short exposures at simulated altitude of 25,000 and 35,000 ft	R-potential in some instances (not consistent).	2
8		Simulated altitude of 19,685 ft	nce from sea level = -1.46 mm (sitting).	3
9		Simulated altitude of 23,000-26,250 ft	l.	4
10		7% O_2-gas mixture	nerally dropped	5
11		Up to 20,000 ft altitude	QRS amplitude	7
12	T	O_2-gas mixture (arterial O_2 saturation = 95-70%)[1]	T wave related to degree of decrease in O_2 saturation. T wave may become diphasic, or with progressive anoxemia	1
13		Short exposures at simulated altitude of 25,000 and 35,000 ft	voltage decrease. Onset of significant changes: = 30-60 sec; 35,000 ft = 10-90 sec.	2
14		Simulated altitude of 35,000 ft[3]	height before hypoxia = 0.675 mv; mean during hypoxia = 0.151 mv (-23%). Wave es diphasic.	8
15		Simulated altitude of 19,685 ft	rence from sea level = -0.83 (sitting).	3
16		Approximately 24,750 ft altitude (alveolar O_2 pressure = 50-60 mm Hg)	of wave began at alveolar O_2 pressure of 50-60 flattening proportional to increase in heart solute loss of height greater in initially higher ls.	9
17		Simulated altitude of 23,000-26,500 ft	quickly reduced to approximately half the previous potential. Flattening increased with increased heart rate and increased hypoxia.	4
18		7% O_2-gas mixture	Lowered amplitude.	5
19		Up to 20,000 ft altitude	Occasionally very slight depression.	7
20		Flights at 15,000 and 20,000 ft[4]	Diminished in all 4 leads	10
21		Continuous exposure to low O_2[2]	Inverted wave.	6
22	ST segment	O_2-gas mixture (arterial O_2 saturation = 95-70%)[1]	Total ST deviation in Leads I-IV increased slightly (up to 25 mm) with increased anoxemia. Most commonly, the incidence of Lead II depression (0.5 mm) increased with increasing hypoxemia.	1
23		Simulated altitude of 19,685 ft	ST above isoelectric line.	3
24		Simulated altitude of 23,000-26,250 ft	ST depressed with progressive hypoxia.	4
25		7% O2-gas mixture	Lowered amplitude.	5
26		Simulated altitude of 16,250 and 20,000 ft	ST_2 depressed at 16,250 ft; ST_1 depressed at 20,000 ft.	11

/1/ Any instance of sinus arrhythmias disappeared when heart rate increased by more than 25 beats per minute. /2/ Development of sinus arrhythmia, shifting pacemaker, and premature atrial and ventricular beats. /3/ Occasionally extrasystoles. /4/ In many cases, U wave appeared.

Contributor: Marbarger, John P.

References. [1] Penneys, R., and C. B. Thomas. 1950. Circulation, N. Y. 1:415. [2] King, B. G., and M. Henson. 1947. J. Aviat. M. 18:3. [3] Doetsch, W. 1938. Luftfahrtmedizin 2:354. [4] Tittel, S. 1940. Ibid. 4:328. [5] Müller, H. 1940. Dissertation. Erlangen. [6] Monge, C. 1943. Physiol. Rev. 23:166. [7] Benson, O. O. 1940. J. Aviat. M. 11:67. [8] Hemingway, A. 1944. Ibid 15:298. [9] Opitz, E., and F. Palme. 1944. Pflügers Arch. 248:387. [10] White, M. S. 1940. J. Aviat. M. 11:166. [11] Rühl, A. 1948. In F. H. Rein, ed. Physiologie. Part I, p. 201.

Part VIII. PULMONARY CIRCULATION: MAN, DOG

	Specification	Pulmonary Arterial Pressure			Pulmonary Capillary Pressure	Pulmonary Pressure Gradient	Pulmonary Resistance	Pulmonary Blood Volume	Reference
		Systolic	Diastolic	Mean					
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Man								
1	Control (20.96% O_2)	16 mm Hg	6 mm Hg	10 mm Hg	5 mm Hg	5 mm Hg	66 dynes sec/cm^5	660 ml/sq m	1
2	Low O_2 (10%)[1]	23 mm Hg	9 mm Hg	15 mm Hg	5 mm Hg	10 mm Hg	119 dynes sec/cm^5	670 ml/sq m	1
3	Change	+44%	+50%	+50%	0	+100%	+80%	+2%	1
4	Control (20.96% O_2)	21.9 mm Hg	6 mm Hg	13.1 mm Hg			1216 dynes sec cm^{-5}		2
5	Low O_2 (10%)[1]	35.1 mm Hg	13 mm Hg	23 0 mm Hg			1407 dynes sec cm^{-5}		2
6	Change	+60.3%	+116 7%	+75.6%			+15.7%		2
	Dog								
7	Control (20.96% O_2)	29 mm Hg	12 mm Hg						3
8	Low O_2 (10%)[1]	26 mm Hg	12 mm Hg						3
9	Change	-10.3%	0						3

/1/ O_2-N_2 mixture.

Contributor. Marbarger, John P

References: [1] Doyle, J. T., J. S. Wilson, and R. B. Warren. 1951. Proj. NM 001 050.01.04. U. S. Naval School of Aviation Medicine, Pensacola, Fla. [2] Motley, M L., et al. 1947. Am. J. Physiol. 150.315. [3] Beard, E. F., et al. 1951. Proj. 21-26-003 (1). USAF School of Aviation Medicine, Randolph Field, Tex

Part IX: INTERVALS OF THE ELECTROCARDIOGRAM: MAN

For additional information on the ECG, see pages 137-141.

	Interval	Condition Producing Hypoxia	Effect	Reference
	(A)	(B)	(C)	(D)
1	PR	Sudden elevation to 23,000 and 26,250 ft	Interval unaltered.	1
2		Continuous exposure to altitude	Interval shortened.	2
3	PQ	7% O_2-gas mixture	Uniform shortening of interval, from 0.01-0.05 sec.	3
4		Unspecified	At first, interval increased with increasing heart rate, later increased with increasing hypoxia.	4
5	PT	19,685 ft simulated altitude	Mean difference from sea level = -0.03 sec.	5
6	QRS complex	Unspecified	Increase to more than 0.1 sec.	6
7		Unspecified	At first, interval increased with increasing heart rate, later increased with increasing hypoxia.	4
8	QT	Unspecified altitude	Interval relatively unaltered during adaptation to altitude.	1
9		Flights at 15,000 and 20,000 ft	Interval prolonged.	7

Contributor: Marbarger, John P.

References [1] Tittel, S. 1940. Luftfahrtmedizin 4.328. [2] Monge, C. 1943. Physiol. Rev. 23:166. [3] Müller, H. 1940. Dissertation. Erlangen. [4] Van Tavel, F. 1943. Helvet. physiol. pharm. acta, Suppl. 1:65. [5] Doetsch, W. 1938. Luftfahrtmedizin 2:354. [6] Schütz, E. 1938. Ibid 2:192 [7] White, M. S. 1940. J. Aviat M. 11.166.

Part XII CARDIAC WORK AND BLOOD PRESSURE AT REDUCED ARTERIAL O_2 SATURATION: MAN

Normal subjects 12 males and 4 females, 19-33 years of age. Anoxemia was induced with oxygen-nitrogen mixtures administered through an anesthesia machine to give the desired levels of arterial O_2 saturation, as measured with the Millikan oximeter. Blood pressure was determined by the standard auscultatory method. The ballistocardiograph used to derive stroke volume, cardiac index, left ventricular work, and maximum cardiac force, is of the Starr high-frequency, horizontal type. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Variable	Arterial O_2 Saturation: 96%	85%			80%			75%			70%		
		Room Air Control	No. of Subjects	Mean Value	% Change	No. of Subjects	Mean Value	% Change	No. of Subjects	Mean Value	% Change	No. of Subjects	Mean Value	% Change
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)
1	Pulse rate, beats/min	68.9	3	82.6	+19.9 (+16.0 to +23.9)	10	87.2	+26.7 (+13.8 to +47.3)	15	91.7	+33.0 (+14.2 to +62.9)	13	94.5	+36.8 (+11.4 to +59.0)
2	Stroke volume, ml/beat	92.3	3	90.8	-1.6 (-3.0 to -0.6)	10	93.1	+0.9 (-12.0 to +7.8)	15	92.1	+0.2 (-15.6 to +12.3)	13	94.3	+2.2 (-7.5 to +16.2)
3	Cardiac index, L/min/sq m	3.48	3	4.14	+18.8 (+12.7 to +24.6)	10	4.45	+27.8 (+6.8 to +58.1)	15	4.71	+35.3 (+14.2 to +68.8)	13	4.97	+42.7 (+20.4 to +84.9)
4	Left ventricular work, kg-m/min	8.12	2	10.43	+28.5 (+21.9 to +35.0)	9	10.97	+35.1 (+23.7 to +58.8)	14	11.32	+39.4 (-10.2 to +73.8)	12	11.26	+51.0 (+28.5 to +108.4)
5	Maximum cardiac force/beat[1]	33.1	3	36.5	+10.1 (-2.2 to +19.0)	10	36.7	+11.0 (-16.2 to +29.4)	15	38.7	+16.8 (-22.1 to +59.2)	13	43.2	+30.7 (+11.8 to +81.9)
6	Maximum cardiac force/min[2]	2275	3	3010	+32.5 (+15.0 to +41.9)	10	3230	+42.2 (+1.8 to +81.6)	15	3710	+63.3 (+9.0 to +140.0)	13	4165	+83.3 (+49.9 to +189.4)
7	Pulse pressure, mm Hg	44.6	2	46.2	+3.5 (-9.8 to +16.9)	8	49.6	+11.2 (-5.9 to +30.3)	14	57.3	+28.5 (-15.1 to +194.0)	12	61.2	+37.2 (-10.0 to +229.2)
8	Mean blood pressure, mm Hg	99.4	2	108.9	+8.2	8	101.8	+2.2 (-11.5 to +10.7)	14	100.0	+0.7 (-23.0 to +6.2)	12	103.9	+4.5 (-49.3 to +13.3)

/1/ MCF/beat = $I + J + I_2 + J_2$, where I_2 and J_2 are amplitudes of the I and J waves in a large complex, and where I and J are amplitudes of the I and J waves in a small complex (see Appendix II, page 360). /2/ MCF/min = MCF/beat x pulse rate.

Contributor: Penneys, Raymond

Reference: Scarborough, W. R., R. Penneys, C. B. Thomas, B. M. Baker, Jr., and R. E. Mason. 1951. Circulation, N. Y. 4 190.

82. HEMODYNAMIC EFFECTS OF HYPOXIA (LOW O_2) (Concluded)

Part XL THE ELECTROCARDIOGRAM, HEART RATE, AND BLOOD PRESSURE AT REDUCED ARTERIAL O_2 SATURATION: MAN

Normal subjects: 73 males and 3 females, 22-28 years of age. Anoxemia was induced with oxygen-nitrogen mixtures administered through an anesthesia machine to give the desired levels of arterial O_2 saturation, as measured with the Millikan oximeter. Blood pressure was determined by the standard auscultatory method. Before inhaling gas mixture, subject rested on a bed until blood pressure and pulse rate became stable. "Absolute change" is from the value for the control on air. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Variable	Arterial O_2 Saturation 80%		75%		70%	
		No of Observations	Absolute Change	No. of Observations	Absolute Change	No. of Observations	Absolute Change
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	T wave height, mm						
1	Lead I	64	-0.68(-2 to +0.5)	67	-0.77(-2.0 to +0.9)	28	-1.19(-2.7 to -0.1)
2	Lead II	64	-1.04(-3.7 to +0.2)	67	-1.33(-4.4 to +1.0)	28	-1.99(-4.7 to -0.5)
3	Lead III	64	-0.37(-1.5 to +0.8)	67	-0.66(-2.6 to +0.9)	28	-1.17(-3.2 to 0)
4	Lead IV	64	-0.75(-2.9 to +3.3)	67	-0.96(-4.3 to +1.9)	28	-1.15(-5.0 to +1.3)
5	RS-T deviation, mm[1]	64	0.60(0-1.5)	67	0.73(0-2)	28	0.86(0-2.5)
6	Heart rate, beats/min	69	+14.0(+1 to +33)	73	+18.3(0 to +39)	30	+23.4(+6 to +39)
	Blood pressure, mm Hg						
7	Systolic	67	+4 1(-11 to +23)	70	+4.1(-13 to +22)	28	+6.3(-4 to +16)
8	Diastolic	67	+0.9(-12 to +13)	70	+0 5(-12 to +12)	28	-0.1(-12 to +10)

/1/ Indicates total for all 4 leads regardless of direction of change from control electrocardiogram.

Contributor: Penneys, Raymond

Reference. Penneys, R., and C. B. Thomas. 1950. Circulation, N. Y. 1:415.

30	Cat, dog	12 cats, 1 dog	Rubber bag	100%	1-4 min	Mean pressure = -2.2	During anesthesia (chloral)	12
31	Rabbit	4			½-1 min	Mean pressure = -1	During anesthesia (urethane)	13
				Cerebral Blood Vessels				
32	Man	15	MSA oxygen mask	Approximately 100%	5 min	Retinal vessels. vasoconstriction	Narrowing of angioscotomata attributed to retinal vasoconstriction	17
33		10	Spirometer	100%	10-15 min	Arterio-venous O_2 difference = +5	Epileptic patients	18
34		6		85-100%	15-30 min	Flow = -13(-28 to +4) Resistance = +35	N_2O technique and ballistocardiogram	14
35		8	Mouthpiece and demand valve	100%	60 min	Arterio-venous O_2 difference = +22.6		19
36				350%	60 min	Arterio-venous O_2 difference = +32.8		
37	Cat	5	Spirometer	100%/3/	15-30 min	Pial vessel diameter = -2	During anesthesia (isoamylethyl barbiturate); skull window	20
38	Monkey	10		100%	2 min	Flow = -20/4/	During anesthesia (nembutal)	21
				Other Blood Vessels				
39	Man	10	Spirometer	100%	10-15 min	Leg vessels: arterio-venous O_2 gradient = -16	Epileptic patients	18
40	Cat		Gas bag	100%	2 min	Pulmonary artery pressure = -10/5/	During anesthesia (chloralose)	22

/1/ Mask check. /2/ Errors of method increased by high O_2 pressure; decrease of pulse rate noted. /3/ Arterial O_2 saturation = 95%. /4/ Approximate figure from graphs /5/ Due mainly to factors other than flow.

Contributor Shephard, Roy J.

References [1] Dripps, R. D., and J. H. Comroe 1947. Am J. Physiol. 149:277. [2] Dautrebande, L., and J. S. Haldane. 1921. J. Physiol., Lond 55:296. [3] Whitehorn, W. V., A. Edelmann, and F A. Hitchcock. 1946. Am. J. Physiol. 146 61. [4] Miller, A. T., H. L. Perdue, E. L. Teague, and J. S. Ferebee. 1952. J. Appl. Physiol. 5:165. [5] Keys, A., J. P. Stapp, and A. Violante. 1943. Am. J. Physiol. 138.763. [6] Benedict, F. G., and H. L. Higgins. 1911. Ibid 28·1. [7] Chiodi, H., J. C. Fasciolo, J. R. Suárez, and A. C. Taquini. 1948. J. Appl. Physiol. 1:148. [8] Alveryd, A., and S. Brody. 1948. Acta physiol. scand. 15·140 [9] Comroe, J. H., R. D. Dripps, P. R. Dumke, and M. Deming. 1945. J. Am. M. Ass. 128:710. [10] Becker-Freyseng, H., and H. G. Clamann. 1939. Klin. Wschr. 18·1382. [11] Richards, D. W., Jr., and A. L. Barach. 1934. Q. J. Med., Oxf. 3.437. [12] Von Euler, U. S., and G. Liljestrand. 1942. Acta physiol. scand. 4:34. [13] Heineman, E. 1943. Ibid. 6:333. [14] Kety, S. S., and C. F. Schmidt. 1948 J. Clin. Invest. 27:484. [15] Otis, A. B., H. Rahn, M. Brontman, L. J. Mullins, and W. O. Fenn. 1946. Ibid. 25:413. [16] Grollman, A. 1930. Am. J. Physiol. 93·19. [17] Rosenthal, C. M. 1939. Arch. Ophth., Chic. 22:385. [18] Lennox, W. G., and E. L. Gibbs. 1932. J. Clin. Invest. 11:1155. [19] Lambertsen, C. J, R. H. Kough, D. V. Cooper, G. L. Emmel, H. H. Loeschcke, and C. F. Schmidt. 1952. J. Appl. Physiol. 5:471, 487, 803. [20] Wolff, H. G., and W. G. Lennox. 1930. Arch. Neur. Psychiat., Chic. 23:1097. [21] Dumke, P. R., and C. F. Schmidt. 1943. Am. J. Physiol. 138·421. [22] Von Euler, U. S., and G. Liljestrand. 1946. Acta physiol. scand. 12:301.

83. HEMODYNAMIC EFFECTS OF HYPEROXIA (HIGH O_2): MAMMALS

All controls breathing air. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal (A)	No. of Subjects (B)	Method of Administration (C)	O_2 Concentration (D)	Exposure Time (E)	Observed Change (% of Resting Value) (F)	Remarks (G)	Reference (H)
	Pulse Rate							
1	Man	33	Face mask and demand valve	100%	1-2 min	-3.7(-12.5 to +4.8)		1
2		2	Douglas bag	100%	5 min	-7.0		2
3		16	Mask and demand valve	100%	5 min	-12.2		3
4		33	Face mask and demand valve	100%	6-8 min	-5.5(-14.4 to +4.8)		1
5		26		100%	10-20 min	No change	During exercise (4 min at 7 mph)	4
6		7	Anesthesia mask	100%	15-20 min	-10(-17.5 to -5)		5
7		6	Spirometer	90%	15-30 min	-6.7(-10.0 to -3.3)		6
8		10		100%	15-30 min	-15.2(-21 to -10)	Anemic patients	7
9		15	Spirometer	100%	20-30 min	-9.1(-17.4 to -4.3)		8
10		16	Mask and demand valve	100%	60 min	-13.9		3
11		28	Mask and demand valve	100%[1]	24 hr	No change		9
12		2	Decompression chamber	90%	65 hr	+15		10
13		2	Oxygen chamber	45%	168 hr	(-13 to -12)	CO_2 rose to 0.5%	11
14	Cat, dog	12 cats, 1 dog	Rubber bag	100%	1-4 min	-3.3	During anesthesia (chloral)	12
15	Rabbit	4		100%	½-1 min	-0.6	During anesthesia (urethane)	13
	Cardiac Output							
16	Man	16	Oxygen mask and demand valve	100%	5 min	-13.0	Ballistocardiogram	3
17		33	Mask and demand valve	100%	6-8 min	-8	Ballistocardiogram	1
18		7	Anesthesia mask	100%	15-20 min	-10(-20 to +19)	Roentgenokymograph	5
19		6		85-100%	15-30 min	-4.9	Ballistocardiogram	14
20		5	Spirometer	100%	30 min	-8.5	Ballistocardiogram	15
21		1	Douglas bag	100%	45 min	Probably no decrease[2]	Acetylene method	16
22		16	Oxygen mask and demand valve	100%	60 min	-19.4	Ballistocardiogram	3
23		2	Oxygen chamber	40-50%	1 wk	No change	CO_2 rose to 0.5%	11
	Systemic Blood Pressure							
24	Man	16	Mask and demand valve	100%	5 min	Systolic pressure = -2.3 Diastolic pressure = +2.1		3
25		7	Anesthesia mask	100%	15-20 min	Increase in systolic and diastolic pressure		5
26		6	Oxygen chamber	85-100%	15-30 min	Systolic pressure = +9.3 Diastolic pressure = +16.7		14
27		15	Spirometer	100%	20-30 min	Systolic pressure = +1.6(-2.5 to +5.7) Diastolic pressure = +5.7(-1.5 to +10.9)		8
28		16	Mask and demand valve	100%	60 min	Systolic pressure = +2.7 Diastolic pressure = +6 9		3
29		28	Mask and demand valve	100%[1]	24 hr	No significant change		9

20		4	BLB[1] mask	5% in air	3	Systolic pressure = +4.2(-2.5 to +10.0) Diastolic pressure = +5.0(+1.2 to +7.5) Mean pressure = +4.5(+1 to +8)	Direct recordings from aorta in subjects with patent ductus arteriosus.	2
21		8	Mouthpiece and demand valve	2.16% in air	8-10	Mean pressure = -1		4
22				4.31%	8-10	Mean pressure = +1.9		
23				5.48%	8-10	Mean pressure = +4.8		
24		2		7% in air	15-30	Systolic pressure = +10.7 Diastolic pressure = +14.6		3
25		6		5% in air	15-30	Systolic pressure = +7.8 Diastolic pressure = +8.8		3
26	Cat		Gas bag	7-14.9% in O_2	0-1	-50	6 min after injection of ergotamine	9
27	Dog	7	Rubber bag and respirator	5-15% in O_2	<20	Normal = (+12 to +34) With curare = -50(-66 to -33)		10
						Blood Flow		
28	Man	16	Rebreathing	0-8% in 30% O_2	17-32	Blood flow, 1% CO_2 = -9.8	Hand blood flow.	11
29						2% CO_2 = -10.0		
30						3% CO_2 = -16.7		
31						4% CO_2 = -19.3		
32						5% CO_2 = -31.5		
33						6% CO_2 = -39.8		
34	Cat	30		0.2-30% in air	2-5	Primary contractions = -9.3 Secondary dilatations = +16.3 After ceasing to breath CO_2 = +29.4	Mesenteric vessels (superior mesenteric, common iliac), during urethane anesthesia. Concentration of 0.5-1.0% CO_2 adequate to produce changes.	12
35	Dog			4-10%	2-4	Decreased flow in both innervated and denervated leg, but effect reversed by prolonged anesthesia (6 hr).	Femoral artery, brachial artery, during urethane anesthesia.	13
36						Increased flow; effect unaltered by denervation.	Superior mesenteric artery.	
37						Quite marked increase.	Aortic arch.	

/1/ Boothby, Lovelace, Bulbulian. /2/ Approximate figure from graphs. /3/ Cardiac output may be initially increased; postulated later failure of venous return. /4/ Functional venesection.

Contributors. (a) Shephard, Roy J., (b) Spencer, Joseph N.

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84. HEMODYNAMIC EFFECTS OF HYPERCAPNIA (HIGH CO_2)

Part I CHANGE IN PULSE RATE, CARDIAC OUTPUT, BLOOD PRESSURE, AND BLOOD FLOW: MAMMALS

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	No. of Subjects	Method of Administration	CO_2 Concentration	Exposure Time min	Observed Change (% of Resting Value)	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
						Pulse Rate		
1	Man	29	Regulator, reservoir, and mask	10.4% in O_2	2-6	+19.5(-5 to +45)		1
2		42	Regulator, reservoir, and mask	7.6% in O_2	2-8	+20.9(-12.5 to +85)		1
3		18	BLB[1] mask	5% in air	3-4	+4.8	16 cases of congenital heart disease, 2 normal subjects. Effect observed only in recumbent position.	2
4		2		7% in air	5-10	+3		3
5		6		5% in air	5-10	+9		3
6		8	Douglas bag	2.16% in air	8-10	-6.4		4
7				4.31% in air	8-10	+0.6		
8				5.48% in air	8-10	+2.1		
9	Hedgehog	8	Gas chamber	3% in O_2	70-240	No change		5
10				6% in O_2	70-240	Hibernating = +20[2] Non-hibernating = +23[2]		
11				9.5% in O_2	70-240	Hibernating = +25 Non-hibernating = +14		
						Cardiac Output		
12	Man	16	BLB[1] mask	5% in air	3	+14(-8.9 to +72.8)	Subjects with congenital heart disease, in recumbent position. Modified direct Fick method.	2
13		4	Douglas bag	0-9% in air	4-40	No effect on circulation rate at 0-6% CO_2; moderate increase with higher concentrations.[3]	Acetylene method.	6
14		2	Cylinder mixtures	2.5-7.5% in air	10,15	Recumbent, 6.5% CO_2 = +66, +60 Upright = -17.5, -20 Legs "empty"[4] = +44 Legs "full" = +20	Acetylene method.	7
15		6	Gasometer and anesthesia mask	2.6% in 10% O_2	15-20	+14(+3 to +45) Diastolic volume = -2.5(-6 to 0)	Roentgenokymograph.	8
16		2		7% in air	15-30	+1.6		3
17		6		5% in air	15-30	+8.5		3
						Systemic Blood Pressure		
18	Man	34	Regulator, reservoir, and mask	7.6% in O_2	2-8	Systolic pressure = +25.6(+10 to +53) Diastolic pressure = +28(+5 to +59)		1
19				10.4% in O_2	2-8	Systolic pressure = +28(+8 to +43) Diastolic pressure = +31(+4 to +77)		

Part III CHANGE IN PULSE RATE, BLOOD PRESSURE, AND THE ELECTROCARDIOGRAM: DOG

Cardiovascular *effects* of breathing high CO_2 concentrations *in the* environmental air vary with the kind of anesthetic, *depth* of anesthesia, the state of the nervous system, experimental procedure, duration of exposure, oxygenation, and, *to a lesser* degree, with the animal species. Symbols: (+) = increase or elevation, (-) = decrease, (0) = no change

	CO_2 Concentration	Exposure Time min	Preparation or Method	Anesthetic	Arterial pH	Pulse Rate	Blood Pressure	QRS Interval	PR Interval	ST Segment	T Wave	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
1	5.0%		Heart-lung			Marked decrease[1]						Ventricular dilatation, increase in coronary blood flow.[1]	1
2		15		Nembutal		-4%	0					Decrease in pulmonary resistance	2
3		9	Open chest	Pentobarbital		-7%	-14%	0	0	Slurring	+	12% decrease in systolic excursion; 13% decrease in contraction force.	3
4		20		Pentobarbital		0	+21%						4
5		20	Artificial respiration	Pentobarbital and curare		+	+6%						4
6	10.0%	10	Heart-lung	Nembutal and succinylcholine	7.2	-						Cardiac dilatation; decrease in cardiac output and systolic excursion.	5
7		13	Open chest	Pentobarbital		-16%	-18%	0	0	Slurring	+	21% decrease in systolic excursion; 24% decrease in contraction force; increased skeletal muscle tonus; increased heart rate and irregularities on return to room air.	3
8		45		Pentothal	7.24	0		0	0	0	+	100% increase in cerebrospinal fluid pressure.	6, 7
9	11.5%		Decerebrate			-		0	+	0	+	Marked decrease in atrioventricular conduction.	8
10	15.0%	3	Heart-lung	Nembutal		-	-					Cardiac dilatation, marked reduction in cardiac output, rise in central venous pressure; sympatho-adrenal system antagonized effect of CO_2 on heart.	5
11		10	Artificial respiration	Nembutal and succinylcholine	7.1	+	0					Vagotomy resulted in 5-10% increase in blood pressure response to CO_2	5

/1/ True also of cat.

84. HEMODYNAMIC EFFECTS OF HYPERCAPNIA (HIGH CO_2) (Continued)

Part II. CHANGE IN PULSE RATE AND BLOOD PRESSURE. MAN

Cardiovascular effects of breathing high CO_2 concentrations in the environmental air vary with the kind of anesthetic, depth of anesthesia, the state of the nervous system, experimental procedure, duration of exposure, oxygenation, and, to a lesser degree, with the animal species. Symbols: (+) = increase or elevation, (0) = no change.

	CO_2 Concentration	Exposure Time min	Anesthetic	Arterial pH	Pulse Rate	Blood Pressure	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	2.5%	15-20	None	7.39	0	0	No effect on cerebral circulation.	1
2	3.5%	15-20	None	7.35	0	0	Cerebral vasodilatation.	1
3	5.0%	3-5	None		0	Systolic = +6% Diastolic = +4%	25% increase in cardiac output; peripheral vasodilatation, increased metabolic rate.	2
4	7.6%	2-7	None		+20 to +30%	Systolic = +22 to +24% Diastolic = +13 to +20%		3,4
5	10.0%	4-20	None		+20 to +30%	Systolic = +25 to +55% Diastolic = +19 to +38%		3,4
6	20.0%	15	Pentothal	7.15	+	+	Return to room air produced slight fall in systolic pressure and marked fall in diastolic pressure.	
7	25.0%	15	Pentothal		+	+	Transient extrasystoles; decrease in plasma volume; fall in blood pressure with return to air	5
8	30.0%	15	Pentothal	6.98	+	+	Transient extrasystoles; decrease in plasma volume.	5
9		10-26	Pentothal	6.8	+	+	Extrasystoles; 10.5% increase in plasma volume; fall in blood pressure with return to room air.	5
10			None			Marked rise.	Marked fall in blood pressure with return to room air.	6
							Muscular tremors; decreased coagulation time.	7

Contributors (a) Spencer, Joseph N., (b) Shephard, Roy J.

References [1] Patterson, J. L., Jr., A. Heyman, L. L. Battey, and R. W. Ferguson. 1955. J. Clin. Invest. 34:1857. [2] Shephard, R. J. 1955. J. Physiol., Lond. 129:393. [3] Dripps, R. D., and J. H. Comroe, Jr. 1947. Am. J. Physiol. 149:43. [4] Seevers, M. H. 1944. N. York State J. M. 44:597. [5] Busse, E. W., T. M. Parry, E. L. Goldensohn, R. W. Whitehead, and W. B. Draper. 1952. Dis. Nerv. Syst. 13:35. [6] Clowes, G. H., Jr., A. L. Hopkins, and F. A. Simeone. 1955. Ann. Surg. 142:446. [7] Leake, C. D., and R. M. Waters. 1929. Current Res. Anesth. 8:17.

												sympathomimetic drugs, increased plasma potassium and coronary flow.	
22	40.0%	45		Pentothal	6.79	+7%		0	0	0	+	150% increase in cerebrospinal fluid pressure; decreased coagulation time	6,7
23		120		Pentothal	6.67							Ventricular fibrillation, circulatory collapse, and death with return to room air.	16
24	50.0%	4	Open chest	Pentobarbital		-28%	-37%	0	0	Slurring	+	68% decrease in systolic excursion; 50% decrease in contraction force, marked decrease in cardiac output, epicardial hemorrhage; marked cardiac dilatation	3
25	60.0%	190		Pentothal	6.46	-43%	-6%	+	+				12
26	70.0%	90	Artificial respiration	Pentothal	6.44	-40%	-28%	0	+			Death due to circulatory collapse.	12
27	80.0%	66	Artificial respiration	Pentothal	6.40	-40%	-40%	0	+			Death due to circulatory collapse.	12

Contributors. (a) Spencer, Joseph N., (b) Shephard, Roy J.

References [1] Vaughan Williams, E. M. 1955. J. Physiol., Lond. 129:90. [2] Stroud, R. C., and H. Rahn. 1953. Am. J. Physiol. 172:211. [3] Boniface, K. J., and J. M. Brown. 1953. Ibid. 172:752. [4] Page, I. H., and F. Olmsted. 1951. Circulation, N. Y. 3:801. [5] Nahas, G. G., and H. M. Cavert 1957. Fed. Proc., Balt. 16:92. [6] Spencer, J. N., T. M. Parry, R. W. Whitehead, and W. B. Draper. 1950. J. Pharm. Exp Ther. 98:366. [7] Goldensohn, E. S., R. W. Whitehead, T. M. Parry, J. N. Spencer, R. F. Grover, and W. B. Draper. 1951. Am. J. Physiol. 165:334. [8] Whitehorn, W. V., and J. W. Bean. 1952. Ibid 168:528. [9] Li, T. H., J. W. Dow, and M. Yamamoto. 1957. J. Pharm. Exp. Ther. 119:160. [10] Richards, J. B., and S. N. Stein. 1957. Am. J. Physiol. 188:1. [11] Leake, C. D., and R. M. Waters. 1929. Current Res. Anesth. 8:17. [12] Brown, E. B., Jr., and F. Miller. 1952. Am. J. Physiol. 170:550. [13] Billings, H. H., and E. B. Brown, Jr. 1955. Ibid. 180:363. [14] Houle, D. B., M. H. Weil, E. B. Brown, Jr., and C. S. Campbell. 1957. Proc. Soc. Exp. Biol., N. Y. 94:561. [15] Brown, E. B., Jr. 1955. Ibid. 90:319. [16] Brown, E. B., Jr., and F. Miller. 1952. Am. J. Physiol. 169:56.

84. HEMODYNAMIC EFFECTS OF HYPERCAPNIA (HIGH CO_2) (Continued)

Part III· CHANGE IN PULSE RATE, BLOOD PRESSURE, AND THE ELECTROCARDIOGRAM: DOG (Concluded)

	CO_2 Concentration	Exposure Time min	Preparation or Method	Anesthetic	Arterial pH	Pulse Rate	Blood Pressure	QRS Interval	PR Interval	ST Segment	T Wave	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
12	15.0%	10		Pentothal and chloralose	7.1							18% decrease in cardiac output and 20% increase in peripheral resistance due to change in pH.	9
13		20		Pentobarbital		+	+20%						
14		20	Artificial respiration	Pentobarbital and curare		+	-30%					Vagotomy, atropine, and carotid sinus denervation had no effect on response; paravertebral ganglionectomy, total sympathectomy, and adrenalectomy doubled response to CO_2.	4
15	20.0%	45		Pentothal	7.05	0		0	0	0	+	Marked rise in cerebrospinal fluid pressure; maximal adrenocortical stimulation.	6,7,10
16				None		Marked increase	Marked increase						11
17	25.0%	12	Open chest	Pentobarbital		-20%	-22%	0	0	Slurring	+	28% decrease in systolic excursion; 42% decrease in contraction force; ventricular dilatation; depression of sino-atrial node and bundle of His; cardiac irregularities with return to room air.	3
18	30.0%	15		None		0	0					Clonic convulsions; anesthesia; decreased coagulation time; increased resistance of RBC to hypotonic solution.	11
19		20	Artificial respiration	Pentobarbital and curare	6.93	+	-38%					Refractory to sympathomimetic drugs.	4
20		30		Pentothal		-18%	0	0	0				12
21		45		Pentothal	6.83	+7%		0	0	0	+	Increased cerebrospinal fluid pressure; decreased coagulation time; contraction of spleen; refractory to	6,7,13-15

AND CO_2 CONTENT OF ARTERIAL BLOOD: MAN

ducer, G-E = measured with glass electrode pH meter, C-R = measured by Cambridge pH meter (Model R) with calculated from pH, CO_2 content, and hematocrit by means of nomogram of Singer and Hastings; B-R = measured of Singer and Hastings Values in parentheses are ranges, estimate "c" (cf. Introduction).

pH	CO_2 Pressure	CO_2 Content

Aged, normotensive, arteriosclerotic subjects, mean age, 64 yr. /5/ Hypertensive subjects without evidence of for 12 subjects. /8/ Mean value for 11 subjects. /9/ 17 observations. /10/ Value in milliequivalents for 6 subjects.

Ibid 32 696 [3] Patterson, J. L., Jr., et al. 1955. Ibid. 34:1857. [4] Richardson, D. W., J. L. Patterson, Jr.,

PRESSURE, AND HEART RATE: MAN

Abbreviations A-C = acetylene, B-C = ballistocardiogram, D-D = dye dilution. Values in parentheses are ranges,

Blood Pressure: Systolic, Control (Air), mm Hg (H)	Blood Pressure: Systolic, Hypercapnia, mm Hg (I)	Blood Pressure: Diastolic, Control (Air), mm Hg (J)	Blood Pressure: Diastolic, Hypercapnia, mm Hg (K)	Heart Rate: Control (Air), beats/min (L)	Heart Rate: Hypercapnia, beats/min (M)	Reference (N)	
106 1	113 3	71.3	75 1	78.5	82 8	1	1
106.1	122 5	71 3	83.0	78 5	90.0		2
100	102	67	69	59	60	2	3
				64	67		4
93	88	55	55	60	64		5
101	122	67	78	74	80		6
108	122	77	78	60	60		7
				59	70		8
	126			63	78		9
102	120	66	72	66	99		10
98	111	82		66	99		11
105 1(75-120)	130.3(105-160)	71.2(50-80)	85.8(70-103)			3	12
134 3(105-150)	168 0(125-220)	87.8(58-108)	107.9(90-130)				13
156 3(120-210)	179.7(140-245)	105.1(80-130)	120.8(100-140)				14
						4	15
							16
104(98-111)	115(108-125)	66(60-71)	74(62-80)	64(55-80)	69(55-85)	5	17
105	119(110-128)	70(69-71)	83(80-85)	67(62-72)	69(65-72)	5	18
				71.4(44-92)	88.5(58-108)	6	19

Henderson apparatus /4/ Figures tabulated are those of a typical experiment and not the mean values of all fundi. /6/ Patients with essential hypertension and definite organic changes in retinal arteries. /7/ Subjects given

Ibid 94.287. [3] Hardgrove, M., G. M. Roth, and G. E. Brown. 1938 Ann. Int. M. 12.488. [4] Asmussen, E.
D W, J. L. Patterson, Jr., and A. Wasserman. Unpublished

Part IV: MEAN PRESSURE, pH, CO_2 PRESSURE,

Abbreviations: D-M = measured with a damped mercury manometer; S-T = measured directly by Stratham trans- appropriate corrections for body temperature; P-V = calculated by nomograms of Peters and Van Slyke; S-H = by bubble method of Riley; V-S = measured with Van Slyke manometric apparatus; N-G = obtained from nomogram

	Subjects		CO_2 Concentration[1]	Exposure Time min	Mean Blood Pressure		
	No.	Condition			Method	Control (Air) mm Hg	Hypercapnia
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	6[2]	Supine and fasting	5.0%	(15-30)	D-M	81(78-84)	90(83-94)
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

/1/ In air. /2/ Young males. /3/ Young, normotensive, non-arteriosclerotic subjects; mean age, 30 yr. /4/ arteriosclerosis; mean age, 51 yr. /6/ Hypertensive, arteriosclerotic subjects; mean age, 55 yr. /7/ Mean value

Contributors: Patterson, John L., Jr., and E. L. Hardie

References: [1] Kety, S. S , and C. F. Schmidt. 1948. J. Clin. Invest. 27:484. [2] Novack, P., et al. 1953. and A. Wasserman. Unpublished.

Part V. CARDIAC OUTPUT, BLOOD

Subjects unanesthetized, unless otherwise specified. Blood pressure determined by auscultatory method. estimate "c" (cf. Introduction).

	Subjects		CO_2 Concentration	Exposure Time min	Cardiac Output		
	No.	Condition			Method	Control (Air) L/min	Hypercapnia
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	16[1]		3.0%[2, 3]	23.5(17-32)			
2			6.0%[2, 3]	23.5(17-32)			
3	4[4]	Supine and fasting	1.52% in air	15	A-C	4.4	4.3
4			1.82% in air	37	A-C	3.6	3.5
5			3.52% in air	40	A-C	4.0	3.8
6			5.93% in air	15	A-C	4.1	4.8
7			6.05% in air	8	A-C	4.4	4 6
8			6.90% in air	15	A-C	5.0	6.2
9			7.49% in air	15	A-C	4.0	5.4
10			7.61% in air	25	A-C	4.0	5 7
11			9.25% in air	5	A-C	4.0	5 7
12	15	Recumbent	10.0% in O_2	5			
13	21[5]	Recumbent	10.0% in O_2	5			
14	9[6]	Recumbent	10.0% in O_2	5			
15	2[7]	Recumbent	6.5% in air	15	A-C	5.15(5.07-5.22)	8.38(8.34-8.42)
16		Tilted +60°	6.5% in air	15	A-C	5.15	4.18
17	6[8]	Supine and fasting	5.0% in air	(15-30)	B-C	4.7(3.5-6.0)	5.9(3.5-6.3)
18	2[8]	Supine and fasting	7.0% in air	(15-30)	B-C	5.0(4.3-5 6)	5.1(4.5-5.7)
19	10[9]	Local anesthesia	7.0% in air	7	D-D	6.40(3.48-18.28)	8.27(5.99-10.78)

/1/ 46 observations. /2/ O_2 concentration of rebreathed air maintained at about 30% /3/ Rebreathing in Larson- experiments. /5/ Patients with essential hypertension, some of whom showed narrowing of arterioles in ocular 1-hour rest period in horizontal position prior to testing. /8/ Young males. /9/ 17 observations.

Contributors: Patterson, John L., Jr., and E. L. Hardie

References: [1] Schneider, E. C., and D. Truesdell. 1922. Am. J. Physiol. 63.155. [2] Grollman, A 1930. 1943. Acta physiol. scand. 6·176. [5] Kety, S. S., and C. F. Schmidt. 1948. J. Clin. Invest. 27·484. [6] Richardson,

HYPERCAPNIA (HIGH CO_2) (Continued)

AND HEART RATE· CAT, DOG, FROG

Ringer's solution equilibrated with a CO_2-O_2 mixture. M-M = artery cannulated and direct blood pressure measured

Values in parentheses are ranges, estimate

Hastings and Sendroy. G-E = measured by glass electrode pH meter.

Blood Pressure: Systolic Change	Mean Arterial: Control (Air)	Mean Arterial: Hypercapnia	Mean Arterial: Change	Heart Rate: Control (Air)	Heart Rate: Hypercapnia	Arterial pH: Method	Arterial pH: Control (Air)	Arterial pH: Hypercapnia	Reference	
	mm Hg	mm Hg	mm Hg	beats/min	beats/min					
(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	
+70 mm Hg									1	1
+54 mm Hg										2
+91 mm Hg										3
+120 mm Hg										4
					Slows slightly				2	5
					Slows markedly					6
				91	78				3	7
				88	78					8
				69	68	H-S	7.34	7.35		9
				86	80	H-S	7.35	7.30		10
				75	64					11
				67	61	H-S	7.34	7.35		12
				72	56					13
			(+10 to +28)						4	14
			(-10 to -30)[5]							15
			-20(-40 to +12)							16
			-40(-106 to +33)							17
Varies[8]				162	70(52-88)	G-E	7.39	6.41	5	18
				154	120	G-E	7.34	6.60	5	19
				184	107	G-E	7.29	6.46		20
				198	126					21
					75	G-E	7.34	6.40		22
-14%					-7%[9]				6	23
-18%					-16%[9]					24
-22%					-20%[9]					25
-37%					-28%[9]					26
	135(107-152)	141(119-152)	+6(0 to +12)	206	184(101-216)				7	27
	[illegible]	[illegible]	+4(-11 to +18)	206	179(106-211)					28
					81(147-205)					29
					83(136-213)					30
					53(129-176)				7	31
					52(130-172)					32
					51(134-167)					33
				[illegible]	19				2	34
				26	26					35
				28	25					36

maximum pressure change attained /5/ Followed by a 10-20 minute increase. /6/ Average concentration at time of varying from 1% every 3 minutes to 2% every minute /8/ At 30% CO_2 in O_2, blood pressure fell sharply, but above control level and remained high until 50-70% CO_2 was reached, but fell precipitously as CO_2 increased above

Ibid 40 279. [3] Marshall, E. K., Jr 1926 J. Pharm Exp Ther. 29.167. [4] Page, I. H., and A. B. Olmsted. K J., and J M Brown. 1953. Ibid 172 752. [7] Brickner, E W., et al. 1956. Ibid 184 275.

Abbreviations: H-P = measured with glass heart plethysmograph, F-P = Fick principle, R-S = perfusion with with mercury manometer, G-M = measured with a Gregg manometer; H-S = measured by calorimetric method of "c" (cf. Introduction).

	Subjects			Anesthetic	CO_2 Concentration	Exposure Time min	Cardiac Output			
	Animal	No.	Condition				Method	Control (Air)	Hypercapnia	Method
								L/min		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Cat		Decerebrate	Curare and chloroform	4.7%[1]	1.83				M-M
2					7.0%[2]	1.33				M-M
3					10.8%[3]	1.58				M-M
4					10.0%[2]	0.67				M-M
5		6	Isolated heart-lung	A.C.E. mixture or chloroform	2-8%		H-P		+	
6					12-20%		H-P		-	
7	Dog	1	Trained	None	4.0%	5	F-P	2.37	2.42	
8					3.8%	5	F-P		2.32	
9					5.4%	5	F-P	2.40	2.27	
10					7.9%	5	F-P	2.65	1.98	
11					5.0%	5	F-P	1.19	1.16	
12					5 5%	5				
13					7.6%	5				
14			Ventilated normally	Pentobarbital	5-15% in O_2	Maximum[4]				M-M
15			Ventilated artificially	Pentobarbital and curare	5-15% in O_2	[illegible]				M-M
16										M-M
17										M-M
18		7	Tracheotomized	Sodium pentothal						M-M
19		1	Tracheotomized	Sodium pentothal	50% in O_2[7]	270				
20					60% in O_2[7]	190				
21					70% in O_2[7]	90				
22					80% in O_2[7]	66				
23		19	Bilateral cervical vagotomy; heart in situ	Pentobarbital and barbital	5% in O_2	9				M-M
24					10% in O_2	13				M-M
25					25% in O_2	12				M-M
26					50% in O_2	4				M-M
27		6	Splenectomized	Sodium pentobarbital	2.3%	23				G-M
28					6.3%	33				G-M
29					10.4%	32				G-M
30					14.1%	26				G-M
31		3	Splenectomized	Sodium pentobarbital	6.5%	33				G-M
32					10.3%	30				G-M
33					14.3%	36				G-M
34	Frog		Isolated heart		16% in O_2		R-S	0.234	0.048	
35					12% in O_2		R-S	0.208	0.039	
36					7% in O_2		R-S	0.280	0.113	

/1/ 20% O_2 in gas mixture. /2/ 25% O_2 in gas mixture. /3/ 19% O_2 in gas mixture. /4/ Inhalation continued until death of animal. /7/ CO_2 concentration was started at 30% and increased by adding 100% CO_2 to mixture at rates immediately recovered to control value or higher. As CO_2 concentration increased, blood pressure usually rose 70%. /9/ From control value.

Contributors: Patterson, John L., Jr., and E. L. Hardie

References: [1] Mathison, G. C. 1911. J Physiol, Lond. 42:283. [2] Jerusalem, E., and E. H Starling. 1910. 1951. Circulation, N. Y. 3 801. [5] Brown, E. B., Jr., and F. Miller 1952 Am. J. Physiol. 170:550. [6] Boniface,

VASCULAR RESISTANCE: CAT, DOG

branch of left coronary artery, I-H = isolated heart, coronaries perfused with blood through which 100% CO_2 bubbled, cannula in anterior descending coronary artery, orifice meter.

Vascular Resistance			Arterial CO_2 Content		Arterial pH		Reference	
Control (Air)	Hypercapnia	Change	Control (Air)	Hypercapnia	Control (Air)	Hypercapnia		
mm Hg/ml/100 g/min		%	vol %					
(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	
					7.2	6.6	1	1
45	43	-4					2	2
15	10	-33					3	3
20	19	-9	15	25	7.7	7.6	4	4
21	13	-38	15	38	7.7	7.4		5
	No change						5	6

J. E., et al. 1947. Am. J. Physiol. 148.582. [3] Anrep, G. V., and R. S. Stacey. 1927. J. Physiol., Lond. 64 187. 135 271.

VASCULAR RESISTANCE. MAN, DOG

eter. Values in parentheses are ranges, estimate "c" (cf. Introduction).

Vascular Resistance			CO_2 Pressure		Reference	
Control (Air)	Hypercapnia	Change	Control (Air)	Hypercapnia		
mm Hg/ml/100 ml/min		%	mm Hg			
(J)	(K)	(L)	(M)	(N)	(O)	
					1	1
13.2	21.6	+64	41[2]	55[2]		2
13.2	27.5	+108	41[2]	64[2]	2	3
30	33	+3				4
45	41	-9	48[2]	64[2]	3	5
6.4	4.6	-28	40[5]	56[5]		6
17.4	28.3	+60			4	7
12.6	8.6	-28			5	8
						9

taining 6.5% CO_2 /4/ Sympathetic innervation blocked by intra-arterial phenoxybenzamine. /5/ Arterial CO_2 Ganglionic blockade with intravenous tetraethylammonium chloride.

D Truesdell 1922. Am J. Physiol. 63 155. [3] Clarke, R. S J. 1957. J. Physiol., Lond. 118 537. [4] Richardson,

Part VII: CORONARY BLOOD FLOW AND

Method: C-C = *closed chest, spontaneous respiration,* bubble flowmeter between carotid artery and circumflex
M-C = Morowitz cannula in coronary sinus, heart-lung preparation; O-C = open chest, artificial respiration,

	Subjects: Animal (A)	Subjects: No. (B)	Anesthetic (C)	Method (D)	CO_2 Concentration (E)	Exposure Time min (F)	Blood Flow: Control (Air) ml/100 g/min (G)	Blood Flow: Hypercapnia ml/100 g/min (H)	Blood Flow: Change % (I)
1	Cat	1		I-H		5	50	75	+50
2	Dog	6	Nembutal, or chloralose and morphine	C-C	5-7%		23	23	0
3		1		M-C	7%		68	98[1]	+45
4		1	Chloralose and morphine	M-C	3%	20	45	50	+11
5					7%	15	45	70	+55
6		5[2]	Barbital and *morphine*	O-C	5-8%			Slight *decrease*	

/1/ Heart volume increased 7.5 ml during hypercapnia. /2/ 14 observations.

Contributors: Richardson, David W., and John L. Patterson, Jr.

References: [1] Trethewie, E. R., and M. M. Hodgkinson. 1955. Q. J. Exp. Physiol., Lond. 40.1. [2] *Eckenhoff,*
[4] Hilton, R., and F. Eichholtz. 1925. Ibid. 59:413. [5] Wegria, R., and H. D Green. 1942. Am. J. Physiol.

Part VIII: LIMB BLOOD FLOW AND

Method: V-P = *venous occlusion plethysmography; S-C = Stewart calorim-*

	Subjects: Animal (A)	Subjects: No. (B)	Extremity (C)	Method (D)	CO_2 Concentration (E)	Exposure Time min (F)	Blood Flow: Control (Air) ml/100 ml/min (G)	Blood Flow: Hypercapnia ml/100 ml/min (H)	Blood Flow: Change % (I)
1	Man	4	Hand	V-P	5.4%	5-6	2(1.5-2.5)	1(0.5-1.5)	-50
2			Hand[1]	V-P	5.4-6.4%	5-7	1.5(1-2)	2(1.0-2.5)	+33
3		6	Hand	S-C	5%	15	6.3(0.9-12.7)	4.3(0.4-8.7)	-32
4					7%	20	6.3(0.9-12.7)	3.6(0.8-6.8)	-43
5		8	Forearm	V-P	6.5%[3]	3	3(1.5-4.0)	3(2-5)	0
6		10	Forearm	V-P	8%	3	2(1.5-3.0)	3(2-4)	+50
7		8	Forearm[4]	V-P	5 or 7%	10 or 5	14(9-21)	24(12-35)	+71
8	Dog	4	Leg[6]	V-P	5%	Maximum[7]	9.5(5-16)	6.8(3-12)	+30
9		5	Leg[6, 8]	V-P	5%	Maximum[7]	9.1(4-12)	12.5(5-23)	+37

/1/ Sympathectomized. /2/ Alveolar CO_2 pressure. /3/ *Vigorous voluntary hyperventilation of gas mixture con-*
pressure. /6/ Anesthetized with chloralose. /7/ CO_2 inspired until maximum circulatory effects noted. /8/

Contributors: Richardson, David W., and John L. Patterson, Jr.

References: [1] Gellhorn, E. 1943. Autonomic regulations. Interscience, New York. [2] Schneider, E. C., and
D. W., et al. 1958. *Clin. Res.* 6:127. [5] Patterson, J. L., Jr., et al. Unpublished.

AND VASCULAR RESISTANCE MAN

flow. Values in parentheses are ranges. estimate "c" (cf. Introduction).

Mean Arterial Blood		Arterial CO_2 Pressure		Arterial pH		Arterio-venous			
(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	
82(78-88)	93(83-110)	43	52	7.38	7.33	6.1	3 8	1	1
91(79-111)	95(82-111)	43	50	7.36	7.30	6 6	4 7	2	2
87(61-107)	90(74-105)	38.4	42.5	7.44	7.39	5.9	6.1	3	3
98(72-144)	95(78-126)	39 4	44.7	7.40	7.35	6.0	5.4	3	4
								4	5
									6
								4	7
									8
132(110-169)	143(92-193)							5	9
112(86-168)	130(95-193)							6	10
95(83-108)	115(98-193)							5	11
136(115-160)	150(110-200)	40	48	7.41	7.35	6 0	4.3	2	12
94(72-115)	98(76-115)	46	53	7.34	7.30	6.3	4.9	2	13
132(117-156)	139(110-172)	38	48	7.41	7.33	7.7	5.1	2	14

32 696. [3] Patterson, J. L., Jr., et al 1955. Ibid. 34.1857. [4] Schieve, J. F., and W. P. Wilson. 1953. Am.
Sc 223-245

VASCULAR RESISTANCE MAN, DOG

estimate "c" (cf Introduction)

Change %	Vascular Resistance Control (Air) mm Hg/ml/min	Vascular Resistance Hypercapnia mm Hg/ml/min	Change %	Mean Blood Pressure Control (Air) mm Hg	Mean Blood Pressure Hypercapnia mm Hg	Change %	Reference	
(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	
-13(0 to -39)			+46(7-110)			+21	1	1
-23(-9 to -66)			+75(23-228)			+16		2
	0 56	0 56		150	152	+1.3	2	3
	0.56	0.51	-8 9	150	142	-5.3		4
	0.56	0.50	-10 7	150	139	-7.3		5
	0 56	0 60	+7 1	150	135	-10		6

progressive hypercapnia, stage IV = 16.8% average CO_2 concentration.

Exp Biol., N. Y. 84.15.

Part IX: CEREBRAL BLOOD FLOW

Nitrous oxide sampling method employed in measuring cerebral blood

	Subjects			CO_2 Concentration[2]	Exposure Time min	Blood Flow			Vascular Resistance		
	No.	Age[1] yr	Condition			Control (Air)	Hypercapnia	Change %	Control (Air)	Hypercapnia	Change %
						ml/100 g brain/min			mm Hg/ml/100 g brain/min		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	
			convalescent								
4	19	35	Convalescent	3.5%	15-30	52(30-68)	57(33-74)	+9.6	2.0(1.2-3.6)	1.8(1.1-3 4)	-10.0
5	29	44	Normal	5%	4	59(55-62)	89(77-105)	+50 8			
6				7%	4	59(55-62)	129(119-139)	+101.7			
7	10	59	Stroke	5%		35	49	+40.1			
8				7%		35	61	+74.2			
9	18	69	Hypertension	5%	10-15	39(25.5-67.6)	47(28.4-77.0)	+20.5	3.6(2.1-4.7)	3.2(1.6-5.1)	-11.1
10	27	71	Cerebral vascular disease	5%	10-15	35(29.6-55.0)	51(35.4-89.9)	+45.7	3.5(2.0-4.3)	2.8(1.0-4 0)	-18.9
11	13	74	Normotension	5%	10-15	35(20.7-63.6)	55.5 (32.7-94.5)	+58.7	2.9(1.4-4.4)	2.2(1.0-3.2)	-24.1
12	6		Essential hypertension	5%	10	52(31-67)	86(72-103)	+65.4	2.6(1.9-3.5)	1.7(1.0-2.3)	-34.6
13	10		Arteriosclerosis	5%	10	47(29-98)	55(33-99)	+17.1	2.1(0.8-3.2)	1.9(0 8-3.0)	-9.8
14			Hypertension, arteriosclerosis	5%	10	36(23-51)	49(24-94)	+36.2	3.7(2.5-6.3)	3.0(1.4-6.0)	-18.9

/1/ Mean. /2/ Lines 1-9, 11-14, CO_2 in 21% O_2, line 10, CO_2 concentration assumed also to be in 21% O_2.

Contributors: Patterson, John L., Jr., and C. L. Carter

References: [1] Kety, S. S., and C. F. Schmidt. 1948. J. Clin. Invest. 27.484. [2] Novack, P., et al. 1953. Ibid. J. Med. 15 171. [5] Fazekas, J F., et al. 1953. J. Geront. 8·137. [6] Fazekas, J. F., et al. 1952. Am. J. M.

Part X. RENAL BLOOD FLOW AND

Values in parentheses are ranges.

	Animal	No. of Subjects	Anesthetic	Method	CO_2 Concentration in O_2	Exposure Time min	Blood Flow	
							Control (Air)	Hypercapnia
							ml/min	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Man, normotension	6			10%	10		
2	Man, hypertension	5			10%	10		
3	Dog	8	Pentobarbital, intravenous	p-Aminohippurate and mannitol	Stage I[2]	30	275	275
4					Stage II[2]	40	275	275
5					Stage III[2]	40	275	275
6					Stage IV[2]	40	275	230

/1/ Renal vascular resistance = mean blood pressure/renal blood flow. /2/ Roman numerals indicate stages of

Contributor. Patterson, John L , Jr

References: [1] Little, W. J., et al. 1949. Fed. Proc., Balt. 8 98. [2] Dowds, E. G., et al. 1953. Proc Soc.

HYPERCAPNIA (HIGH CO_2) (Concluded)

PULMONARY ARTERIAL PRESSURE: MAMMALS

spontaneous breathing, I-R = isolated, perfused lung, *open*-circuit respiration; I-T = isolated, perfused lung, 20 ml
P-A = *isolated*, perfused lung, 8% CO_2 equilibrated with perfusate. Values in parentheses are ranges, estimate "c"

Blood Flow, Control (Air), L/min (G)	Blood Flow, Hypercapnia, L/min (H)	Blood Flow, Change (I)	Mean Arterial Pressure, Control (Air), mm Hg (J)	Mean Arterial Pressure, Hypercapnia, mm Hg (K)	Mean Arterial Pressure, Change (L)	Reference (M)	
			19(12-25)	20(16-27)	+4%	1	1
5 5(4-10)	8 0(6-11)	+45%				2	2
9 1(4-17)	10.8(7-23)	+18%	31(11-77)	34(12-84)	+10%	3	3
4 6(2-9)	5.1(2-10)	+11%	14(8-30)	15(7-30)	+11%	4	4
			13	15	+10%[3]	5	5
			20	18	-8%[3]		6
			20	18	-8%		7
			19	21	+12%		8
	Increased		14	15	+11%	6	9
	Decreased		21	16	-25%		10
	Decreased		18	16	-9%		11
3 1(2.6-3.7)[b]	3 3(2.7-3 9)[b]	+6%	27(19-34)[b]	27(21-34)[b]	+2%	7	12
			30	31(29-34)	+3%	8	13
			30	30(29-33)	+1%		14
					+(5-16) mm Hg	9	15
					+(9-12) mm Hg		16
					+(12-15) mm Hg		17
			12(9-22)	15(10-25)	+25%	3	18

after anesthesia. /5/ Observations, not subjects. /6/ 21 observations.

Res 7:136. [3] Hebb, C. O., and R. H. Nimmo-Smith. 1949. Q J. Exp. Physiol., Lond. 34.159. [4] Shephard, R. J. 1951. Ibid, 23 85,361. [7] Stroud, R. C., and H. Rahn. 1953. Am. J. Physiol. 172:211. [8] Duke, H. N. 1950. Q. J.

RESISTANCE, AND HEPATIC VASCULAR RESISTANCE. DOG

spirometer never decreased below 21 volumes per cent. CO_2 concentration is mean per cent obtained *from* 3-7
Values in parentheses are ranges, estimate "c" (*cf. Introduction*).

Mesenteric Vascular Resistance[2], Control (Air), mm Hg/ml/min (L)	Mesenteric Vascular Resistance[2], Hypercapnia, mm Hg/ml/min (M)	Change % (N)	Inferior Vena Caval Pressure, Control (Air), mm Hg	Inferior Vena Caval Pressure, Hypercapnia, mm Hg	Hepatic Vascular Resistance[3], Control (Air), mm Hg/ml/min	Hepatic Vascular Resistance[3], Hypercapnia	Hepatic Vascular Resistance[3], Change %	
								1
								2
								3
								4
								5
								6
								7

/3/ Calculated from. $\frac{\text{portal venous pressure - inferior vena caval pressure}}{\text{blood flow}}$. /4/ 0% CO_2 in spirometer at start of

Part XI: PULMONARY BLOOD FLOW AND MEAN

Method: C-C = cardiac catheter, direct Fick; D-D = dye dilution, antecubital dye injection; S-B = closed chest, of pure CO_2 injected rapidly into trachea; P-X = isolated, perfused lung, 10% CO_2 equilibrated with perfusate, unless otherwise indicated (cf. Introduction).

	Animal	No. of Subjects	Anesthetic	Method	CO_2 Concentration	Exposure Time min
	(A)	(B)	(C)	(D)	(E)	(F)
1	Man	5	Seconal	C-C	5%	5-10
2		10		D-D	7%	7
3	Man, congenital heart disease	8[1]		C-C	5%	3
4		12[2]		C-C	5%	3
5	Cat	1	Chloralose	S-B	3%	
6					6.5%	
7					18.7%	
8					20.5%	
9		2		I-R	8%	4
10		1		P-X	10%	6
11		1		P-A	8%	6
12	Dog	5	Nembutal	C-C	5%	10-15
13		10[4]	Nembutal	I-R	5%	21-73
14		60[4, 5]	Nembutal	I-R	10%	21-73
15				I-R	10%	31-45
16					20%	31-45
17					30%	31-45
18	Monkey, rhesus	2[4, 6]	Nembutal	I-T	100%	

/1/ Without pulmonic stenosis. /2/ With pulmonic stenosis. /3/ Left atrial pressure unchanged. /4/ Bled to death

Contributors: Richardson, David W., and John L. Patterson, Jr.

References: [1] Westcott, R. N., et al. 1951. J. Clin. Invest. 30:962. [2] Richardson, D. W., et al. 1959. Clin. 1954. Brit. Heart J. 16:451. [5] Euler, V., and G. Liljestrand. 1946. Acta physiol. scand. 12:301. [6] Nisell, O. Exp. Physiol., Lond. 35:25. [9] Binet, L., and F. Bourliere. 1941. C. rend. Soc. biol. 135:449.

Part XII: MESENTERIC BLOOD FLOW AND VASCULAR

Hypercapnia (divided into 4 stages) was produced by rebreathing from a segment spirometer. O_2 content of analyses of spirometer gas per stage of hypercapnia. Blood flow measured with a Shipley-Wilson rotameter.

No. of	CO_2		Exposure	Mean Arterial Blood Pressure (Systemic)	Mesenteric Blood Flow	Portal Venous Pressure
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

/1/ Anesthetized with pentobarbital. /2/ Calculated from: $\frac{\text{mean arterial blood pressure - portal venous pressure}}{\text{blood flow}}$.

experiment. /5/ 4.6% CO_2 in spirometer at start of experiment.

Contributors: Patterson, John L., Jr., and E. L. Hardie

Reference: Brickner, E. W., E. G. Dowds, B. Willets, and E. E. Selkurt. 1956. Am. J. Physiol. 184 275.

88. EFFECT OF BREATHING AIR AT 4 ATMOSPHERES ON PULMONARY ARTERIAL PRESSURE. RAT

Following prolonged exposure (4-6 weeks) in compressed air (O_2 pressure = 0.7-1.0 atmosphere), pulmonary arteriolar lesions (thickening and hyalinization leading to thrombosis) develop and later degenerative lesions of the large arteries of the lungs. The obliterative vascular changes are followed by a rise in pulmonary pressure, enlargement of the right ventricle, and a fall in systolic pressure. O_2 pressure of 4 atmospheres = 635 mm Hg. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	No. of Rats	Duration of Exposure da	Pulmonary Arterial Pressure[1] cm H_2O
	(A)	(B)	(C)
1	5	3	207(133-234)
2	5	10	244(176-304)
3	5	17	255(163-425)
4	5	24	318(279-394)
5	5	31	409(322-597)
6	3	38	423(322-529)

/1/ Control average for 34 rats = 256 cm H_2O

Contributor. Behnke, A. R.

Reference. Bennett, G. A., and F. J. C. Smith 1934. J. Exp M 59 181.

89. EFFECT OF RECOMPRESSION, WITH O_2 AND WITH AIR, ON ARTERIAL BLOOD PRESSURE DOG

All values are for blood pressure, in mm Hg. Compression period = 105 minutes at 65 lb/sq in. gauge pressure

	Control Period[1]	Asphyxial Period[2]		Recompression Period[3]	Postrecompression Period[4]
		High	Low		
	(A)	(B)	(C)	(D)	(E)
				Breathing O_2	
1	127	166	64	104	100
2	102	110	62	74	74
3	117	136	60	115	
4	116	140	30	90	100
5	150	172	68	90	80
6	158	166	84	60	65
				Breathing Air	
7	147	154	80	106	102
8	97	104	62	80	85
9	142	130	78	122	80
10	115	128	54	100	108
11	128	162	86	124	125
12	132	137	80	86	114
13	146	120	64	90	90

/1/ In air at 1 atmosphere /2/ Following rapid decompression in 5-6 seconds. /3/ Breathing at 30 lb/sq in. for 1½ hours. /4/ 1 hour following recompression period.

Contributor: Behnke, A. R.

Reference. Behnke, A. R. 1945 Medicine, Balt 24 381

85. PRESSURE EQUIVALENTS

	Atmospheres	mm Hg	Absolute lb/sq in.	Gauge lb/sq in.	Diving Depth ft
	(A)	(B)	(C)	(D)	(E)
1	1	760	14.7	0	0
2	2	1520	29.4	14.7	33
3	3	2280	44.1	29.4	66
4	4	3040	58.8	44.1	99
5	5	3800	73.5	58.8	132
6	6	4560	88.2	73.5	165
7	7	5320	102.9	88.2	198
8	8	6080	117.6	102.9	231
9	9	6840	132.3	117.6	264
10	10	7600	147.0	132.3	297

Contributor: Behnke, A. R.

86. EFFECT OF COMPRESSION ON PULSE RATE, SYSTOLIC BLOOD PRESSURE, AND PULSE PRESSURE: MAN

Tests conducted in pressure chamber. Values expressed as per cent of sea level values.

	Atmospheres	Pressure mm Hg	Pulse Rate			Blood Pressure		Pulse Pressure	
			Reclining	*Standing*	*Exercising*	*Reclining*	*Standing*	*Reclining*	*Standing*
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	1	760	98.8	100.0	100.0	113.8	119.3	48.2	38.3
2	2	1520	90.7	91.6	92.8	106.2	113.2	37.2	26.9
3	4	3040	86.6	86.6	88.4	108.9	113.9	41.6	32.5
4	6	4560	89.4	89.9	89.3	107.2	113.7	34.9	26.8
5	7	5320	83.8	87.4	85.2	108.5	112.0	36.7	24.0
6	10	7600	90.7	84.0	85 2	109.0	126 0	30 0	30.0

Contributor: Behnke, A. R.

Reference: Shilling, C. W., J. A. Hawkins, and R. A. Hansen. 1936. U. S. Nav. M Bull. 34 39.

87. EFFECT OF BREATHING O_2 AT 3-4 ATMOSPHERES ON RESPIRATORY RATE, PULSE RATE, AND BLOOD PRESSURE: MAN

Period: C = control period of air-breathing at one atmosphere, E = experimental period of O_2-breathing at increased ambient pressure. Other effects: O = none discernible, P = pallor, T = twitching movements of a myoclonic nature, M = mental confusion, G = generalized type of convulsions, S = sweating. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	No. of Subjects	Period	O_2 Pressure atmospheres	Respiratory Rate breaths/min	Pulse Rate beats/min	Blood Pressure		Other Effects
						Arterial mm Hg	Internal Jugular mm Hg	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	1	C	0.2	10	73	96	11.3	
2		E	3.0	11	61	102	9.0	O
3	7	C	0.2	15(12-19)	67(53-87)	78(59-97)	10.7(8.2-17.2)	
4		E	3.5	16(11-20)	59(49-71)	86(75-108)	8.9(5.5-13.2)	O
5	1	C	0.2	11	49	77	9.6	
6		E	3.5	10	48	79	7.9	P
7	3	C	0.2	14(10-17)	68(56-76)	79(72-85)	8.3(8 0-8 7)	
8		E	3.5	21(10-32)	63(61-66)	80(76-82)	6.1(4.1-7.4)	T
9	1	C	0.2	20	75	87	10 0	
10		E	3.5	12	51	91	9.6	P, T, G, S
11	1	C	0.2	19	79	85	6.5	
12		E	4.0	19	78	89	5 4	P, T, G, S
13	1	C	0.2	7	63	79	6.0	
14		E	4.0	12	59	86	4.8	P, M
15	1	C	0.2	13	79	78	5 5	
16		E	4.0		66	85		T, M, S

Contributor: Behnke, A. R.

Reference: Lambertsen, C. J , R. H. Kough, D. Y. Cooper, G. L. Emmel, H. H. Loeschcke, and C. F. Schmidt. 1953. J. Appl. Physiol. 5 471

88. EFFECT OF BREATHING AIR AT 4 ATMOSPHERES ON PULMONARY ARTERIAL PRESSURE: RAT

Following prolonged exposure (4-6 weeks) in compressed air (O_2 pressure = 0.7-1.0 atmosphere), pulmonary arteriolar lesions (thickening and hyalinization leading to thrombosis) develop and later degenerative lesions of the large arteries of the lungs. The obliterative vascular changes are followed by a rise in pulmonary pressure, enlargement of the right ventricle, and a fall in systolic pressure. O_2 pressure of 4 atmospheres = 635 mm Hg. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	No. of Rats	Duration of Exposure da	Pulmonary Arterial Pressure[1] cm H_2O
	(A)	(B)	(C)
1	5	3	207(133-234)
2	5	10	244(176-304)
3	5	17	255(163-425)
4	5	24	318(279-394)
5	5	31	409(322-597)
6	3	38	423(322-529)

/1/ Control average for 34 rats = 256 cm H_2O

Contributor: Behnke, A. R.

Reference: Bennett, G. A., and F. J. C. Smith. 1934. J. Exp. M. 59:181.

89. EFFECT OF RECOMPRESSION, WITH O_2 AND WITH AIR, ON ARTERIAL BLOOD PRESSURE: DOG

All values are for blood pressure, in mm Hg. Compression period = 105 minutes at 65 lb/sq in. gauge pressure.

	Control Period[1]	Asphyxial Period[2] High	Asphyxial Period[2] Low	Recompression Period[3]	Postrecompression Period[4]
	(A)	(B)	(C)	(D)	(E)
				Breathing O_2	
1	127	166	64	104	100
2	102	110	62	74	74
3	117	136	60	115	
4	116	140	30	90	100
5	150	172	68	90	80
6	158	166	84	60	65
				Breathing Air	
7	147	154	80	106	102
8	97	104	62	80	95
9	142	130	78	122	80
10	115	128	54	100	108
11	128	162	86	124	125
12	132	137	80	86	114
13	146	120	64	90	90

/1/ In air at 1 atmosphere. /2/ Following rapid decompression in 5-6 seconds. /3/ Breathing at 30 lb/sq in. for $1\frac{1}{2}$ hours. /4/ 1 hour following recompression period.

Contributor: Behnke, A. R.

Reference: Behnke, A. R. 1945. Medicine, Balt. 24:381.

90. EFFECT OF EXPLOSIVE DECOMPRESSION ON HEART RATE AND ARTERIAL PRESSURE: MAMMALS

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Animal	No. of Subjects	Rate of Decompression mm Hg/sec	Range of Decompression mm Hg	Heart Rate	Arterial Pressure	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Man	150[1]	(38-1310)	(564-179) to (253-111)	Occasional sinus tachycardia associated with apprehension.	No reported or observed circulatory signs or symptoms.	No significant changes in configuration of ECG.	1
2	Dog	45[2]	(1,200-33,650)	(522-87)	Transient bradycardia at rates greater than 8520 mm Hg/sec, followed by recovery.	Transient fall, proportional to rate and range of decompression, followed by recovery.	Anesthetized (nembutal).	2
3		8[3]	3280	(522-30)	Bradycardia.	Fall to 60 mm Hg, then constant during period of decompression.	Anesthetized (nembutal).	3
4		15	33,650	(560-30)	Bradycardia following moment of decompression.	Fall to 70 mm Hg 30 sec after decompression, then essentially unchanged during 1-min exposure to low pressure.	Anesthetized (nembutal). Disappearance of arterial pulse within 30 sec after decompression; recovery usual after recompression.	4
5		8[4]		(520-30) or (180-30)	Bradycardia, premature beats, paroxysmal tachycardia, heart block.	Gradual fall to 50-70 mm Hg within 15 sec of decompression, then constant for remainder of 1-min exposure.[5]	Unanesthetized. Gradual decrease and disappearance of arterial pulse pressure; occasional atypical elevation of arterial pressure.	5
6	Monkey	105[6]	Approximately (1000-4000)	(349-27), (522-76), or (750-93)	Transient bradycardia followed by recovery and secondary "anoxic fall," if animal retained at low pressure.		Anesthetized and unanesthetized animals.	6
7	Rat	250	Approximately 3000	(349-186) to (349-27)	Transient bradycardia followed by recovery and secondary "anoxic fall."		Anesthetized and unanesthetized animals.	7

/1/ 554 observations. /2/ 52 observations. /3/ 24 observations. /4/ 8 observations. /5/ Venous pressure increases suddenly to 25-35 mm Hg during period of decompression. /6/ 202 observations.

Contributor: Whitehorn, William V.

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91. EFFECT OF EXPLOSIVE DECOMPRESSION ON ARTERIAL PRESSURE· DOG

Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I. FINAL PRESSURE GREATER THAN THEORETICAL VAPOR PRESSURE OF BODY FLUIDS

Section 1: Effect of Decompression from 522-87 mm Hg (10,000-50,000 ft) at Varying Rates

	No. of Dogs	No. of Observations	Rate of Decompression mm Hg/sec	Blood Pressure mm Hg	Cardiac Slowing
	(A)	(B)	(C)	(D)	(E)
1	7	8	1200	24(0-40)	None
2	13	19	4800	28(0-50)	None
3	10	10	8520	28(5-65)	Occasional
4	10	10	13,460	50(32-80)	Present
5	5	5	33,650	81(75-100)	Present

Section 2. Effect of Decompression at Rate of 4800 mm Hg/sec and at Varying Intervals in Range of Decompression

	No. of Dogs	No of Observations	Interval in Range of Decompression mm Hg	Blood Pressure mm Hg
	(A)	(B)	(C)	(D)
1	1	1	673	70
2	13	19	435	28(0-50)
3	5	5	375	14(0-25)
4	5	5	300	9(0-12)
5	5	5	275	3(0-12)

Section 3 Effect of Increased Expiratory Resistance at Decompression Rate of 4800 mm Hg/sec and Range of 522-87 mm Hg

	Diameter of Expiratory Opening mm	Blood Pressure mm Hg	Cardiac Slowing
	(A)	(B)	(C)
1	15 (normal)	0	None
2	15 (normal)	10	None
3	15 (normal)	18	None
4	4 5	45	Present
5	2 5	55	Present
6	1 0	60	Marked

Contributor· Whitehorn, William V.

Reference Whitehorn, W. V , A. Lein, and A. Edelmann. 1946 Am. J. Physiol 147:289.

Part II FINAL PRESSURE LESS THAN THEORETICAL VAPOR PRESSURE OF BODY FLUIDS

Decompression from 560-30 mm Hg Arterial pressures for 14 controls systolic = 164(95-190) mm Hg, diastolic = 124(85-165) mm Hg

	No of Observations	Time after Decompression sec	Mean Arterial Blood Pressure mm Hg	Pulse Pressure Observation Present	Pulse Pressure Observation Absent
	(A)	(B)	(C)	(D)	(E)
1	14	10	73 6(50-97)	6	8
2	13	30	70 7(50-97)	3	10
3	12	45	76 1(52-97)	2	10
4	5	60	71.8(60-75)	1	4

Contributor· Whitehorn, William V

Reference. Whitehorn, W. V. 1948. Fed. Proc., Balt 7 133.

[illegible] agents used, depth of anesthesia, differences in strength and duration of acceleration patterns, and variations in the rates of acceleration. *G* = the acceleration of a freely falling body due to the attraction of gravity, expressed as the rate of increase of velocity per unit of time.

	Variable (A)	Animal (B)	Effect (C)	Reference (D)
			Positive (headward) Acceleration	
	Blood pressure			
1	Arterial	Man	At 2.5 G, minimum systolic pressure for clear vision (eye level) = >50 mm Hg. At 3.5 G, minimum systolic pressure for dimming of vision (eye level) = 45 mm Hg. At 4.0 G, minimum systolic pressure for "grayout" (eye level) = 25 mm Hg. At 4.5 G, minimum systolic pressure for "blackout" (eye level) = <20 mm Hg. At 5.0 G, systolic pressure for unconsciousness (eye level) = 0.	1-3
2			Reflex blood pressure recovery due to carotid-sinus-induced vasoconstriction abolished by administration of tetraethylammonium ion.	4
3		Cat, monkey, anesthetized	Carotid pressure falls to zero at 3.4 G or more.	5,6
4		Dog; anesthetized	Carotid pressure falls 1-2 sec after onset of G; at heart level, after 3-8 sec lag Reflex blood pressure recovery in 9-20 sec. Vascular collapse in susceptible subjects.	7
5		Dog, monkey, unanesthetized	Inverse relation between carotid pressure and pulse rate (Marey's Law) well developed in primate, less perfect in dog Man and monkey have a functional advantage of 0.5-1.0 G over dog, because of greater circulatory shifts in dog.	8,9
6		Monkey, anesthetized	Carotid pressure falls with no lag Femoral pressure at first increased and then decreased below normal.	10
7	Venous	Man	Jugular bulb. subatmospheric pressures as great as -60 mm Hg maintain cerebral arterio-venous pressure gradient. Forearm and saphenous venoconstriction demonstrated by isolated venous segment technique.	11,12
8		Cat, monkey, anesthetized	Abdominal venous pressure obeys hydrostatic laws. In peripheral leg veins, pressure builds up slowly due to effect of valves. Parallel changes in sagittal sinus and subarachnoid pressure Jugular collapse.	6,13
9		Dog, anesthetized	Saphenous venoconstriction demonstrated with miniature balloon technique	14
10		Dog, monkey, unanesthetized	Jugular vein pressure falls 25-50%	8
11	Atrial	Cat, rabbit, anesthetized	Atrial pressure falls as much as 43 mm Hg below atmospheric; partially offset by fall in intrapleural pressure.	5,15
12	Renal	Goat, anesthetized	Arterial pressure decreases, venous pressure increases with reduced arterio-venous pressure gradient.	16
	Heart rate and rhythm			
13	Rate	Man	Immediate increase to maximum values of 160-180 beats/min. depending on stress; marked vagal slowing following test, with secondary increase. Increase nearly independent of initial rate [illegible]	4,7,17,18
14		[illegible]	[illegible] ns (3 min or more).	19
15		Monkey, anesthetized	No change during 5-sec exposure	10

	Variable (A)	Animal (B)	Effect (C)	Reference (D)
			Positive (headward) Acceleration (continued)	
	Heart rate and rhythm (concluded)			
16	Rate (concluded)	Rabbit; anesthetized	Decreases with long exposure	15
17	ECG	Monkey, rabbit, unanesthetized	PR, QT, and cycle length consonant with heart rate change; R and S wave changes associated with changes in position of heart in chest; rarely T-wave changes (flattening, biphasic). Displacement of pacemaker during deceleration. In severe cases, atrioventricular block or ventricular rhythm. Electrical axis shifts 10-15° with G-exposure in monkeys.	7,17,19
18	Arrhythmias	Man	Marked sinus arrhythmia, ventricular extrasystoles, bundle branch block.	7,17
	Blood flow			
19	Cardiac output	Man	Estimated by X ray: marked reduction in cardiac shadow.	17
20		Cat, monkey; anesthetized	Estimated by X-ray cinematography with thorotrast: decrease in systolic and diastolic heart shadow, lack of movement of heart contours (principal change is in ventricular length); decreased systolic and diastolic residual. Ultimately heart remains in contracted state	7
21	Cerebral circulation	Man	Cerebral venous O_2 saturation preserved in spite of markedly diminished carotid arterial pressure (30 mm Hg), suggests compensatory effects maintain cerebral blood flow.	11
22		Cat, monkey, anesthetized	Motion pictures of cerebral vessels through a Forbes window: blanching of cerebral surface, retention of blood (stasis) in large vessels, reactive hyperemia afterward	6
23		Dog, monkey; unanesthetized	Venturimeter in carotid: in standard 10-sec run, flow reaches minimum in 4-6 sec, generally corresponding to carotid pressure, flow = 0 at 3-4 G, may be negative at higher G, depression of flow proportional to Δ G/G, rebound after run to 25% above normal	19
24		Rabbit, anesthetized	Thermostromuhr: decrease in carotid flow.	20
25	Retinal circulation	Man	Ophthalmoscopic examination: arteriolar pulsation followed by arteriolar exsanguination and collapse at blackout. Transient venous distension during recovery.	21
26		Monkey, anesthetized	Direct cannulation of retinal artery: decrease in retinal blood pressure.	6
27	Pulmonary circulation	Man	Indirect evidence for pulmonary blood pooling. Changes in vital capacity demonstrate pulmonary blood reservoir function.	22,23
28		Cat, monkey, anesthetized	X-ray cinematography: apical clearing, increased density at bases.	7
29	Ear lobe	Man	Ear opacity diminished (amount related to G level). Ear pulse: increased amplitude at low G; amplitude bears close relation to systolic pressure at head level when pressure is below 50 [illegible]	2,3,17,18
30	Peripheral circulation	Man	M[illegible] ...g veins.	17
31			Plethysmography: increase in volume of lower leg. 500 ml stored at normal temperature in thighs and buttocks during orthostasis (1 G), double this amount at elevated temperatures. Following administration of tetraethylammonium ion, increase in rate of pooling but no increase in amount pooled	4,7,23

	Variable (A)	Animal (B)	Effect (C)	Reference (D)
			Positive (headward) Acceleration (concluded)	
	Blood flow (concluded)			
32	Peripheral circulation (concluded)	Cat; anesthetized	X ray with contrast media: vascular engorgement of liver and lung bases and distensions of iliac and femoral veins.	24
33		Goat; anesthetized	Short-duration, high-magnitude G produces edema, congestion and hemorrhagic changes.	22
34	Blood constituents	Man	3.5-5.0 G for 3-5 min (blackout level) produces a fluid loss of 3.6-4.5 ml/100 ml blood. Humans less sensitive than animals to G-induced fluid loss.	25
35		Goat, anesthetized	Following onset of G, venous hemoconcentration occurs (red cell and plasma protein concentration increased 10-15% above control); arterial hemoconcentration (3-6%) lags venous changes 1.5-2.5 min; during G, protein leakage and red cell packing reported, increase in tissue pressure; rapid post-run dilution.	22
36		Cat, monkey, rat, anesthetized	Hyperglycemia without glycosuria; liver, heart and skeletal muscle glycogen values reduced, serum K and NaCl unaffected; no change in organ water content, blood cell volume increased 20%; blood volume decreased 2%.	24
	Respiratory effects			
37	Rate of breathing	Man	Increases.	7,22
38		Cat, rabbit; anesthetized	Decreases.	5,15
39		Dog, monkey; unanesthetized	Brief increase followed by decrease of 50% post-run increase of 5-10% over control	19
40	*Depth of breathing*	Man	*Early respiratory* amplitude *large; later minute* volume maintained by rate increase.	7,22
41		Cat; anesthetized	Shallow.	5
42		Dog, monkey; unanesthetized	*Brief early increase in depth, then decrease.*	19
43	Intrapleural pressure	Cat; anesthetized	Decreases.	5
44	Lung volumes	Man	Shift in midposition of chest due to visceral movement, increased end-expiratory volume and decreased vital capacity, *changes in vital* capacity related in part to fluctuation in pulmonary blood volume during orthostasis.	7,26,27
45	O_2 intake	Man	Markedly decreased values	22
			Negative (footward) Acceleration	
	Blood pressure			
46	Arterial	Man	In absence of cardiac arrhythmias, *radial arterial* pressure (wrist at head level) increases 70-90 mm Hg at 3 negative G for 15 sec, increases rapidly at first, then gradually falls. *(See line 64.)*	28
47		Cat, anesthetized	Carotid pressure increases more than venous pressure.	13
48		Dog, anesthetized	Prolonged asystole results in gross fall in carotid arterial pressure, when asystole is abolished by vagotomy, arterial pressure increases	29
49		Goat, anesthetized	Carotid pressure increases At 12-15 negative G for 6-30 sec, arterial pressure may increase to 6 times *normal.*	29
50		Monkey, anesthetized	More resistant to arterial pressure effects of negative acceleration than other animals, response *most nearly resembles that in man.*	9
51	Venous	Man	Frontal vein pressure increases linearly with G due to hydrostatic column based at heart level *Initial rapid increase followed by slow steady* rise due to blood drainage from legs.	28-30

	Variable (A)	Animal (B)	Effect (C)	Reference (D)
	Negative (footward) Acceleration (continued)			
	Blood pressure (concluded)			
52	Venous (concluded)	Cat; anesthetized	Jugular pressure directly and linearly related to cerebrospinal fluid pressure. Level of zero venous pressure change in jugular and cerebral spinal fluid located at diaphragm in cat and goat.	13,29
53		Dog, monkey, anesthetized	Jugular pressure more rapid, and greater but more irregular pressure changes occur under negative than under positive G.	8
54		Goat; anesthetized	Jugular: 12-15 negative G for 6-30 sec increases venous pressure to 400-500 mm Hg	29
55		Monkey, anesthetized	Jugular: initial transient venous pressure fall before hydrostatic rise.	31
	Heart rate and rhythm			
56	Rate	Man	Bradycardia in proportion to amount of negative G and its duration.	20,28,29
57		Dog, monkey; anesthetized	Heart rate varies inversely and specifically in relation to carotid sinus pressure changes, particularly in the primate.	8
58		Dog, goat, monkey, anesthetized	Bradycardia. At 2-6 negative G for 5-15 sec, 15 monkeys showed no change, 16 monkeys an average decrease of 8 beats/min, and 41 monkeys an average increase of 3 beats/min. No significant change observed in dogs.	19,31
59	ECG	Man	Bradycardia, ectopic beats. Atrioventricular nodal rhythm with ectopic coupled beats. Prolonged PR interval proceeding to atrioventricular block, with increasing negative G or increased duration. Extrasystoles ventricular in origin, longest asystole = 9 sec.	28,29,32
60		Dog, monkey, anesthetized	Bradycardia, extrasystoles, sinus arrhythmia, large amplitude T waves. Signs of vagal heart block abolished by vagotomy.	28,29,33
	Blood flow			
61	Cardiac output	Man	Estimated by X ray: no measurable cephalad displacement of heart at 3 negative G.	28
62		Dog, goat, anesthetized	Prolonged asystole in animals with intact cardiovascular reflexes results in fall in cardiac output. Peripheral reflex changes absent in goat.	29,31
63	Cerebral circulation	Man	Prolonged asystole results in cessation of cerebral blood flow similar to carotid sinus syncope.	29
64		Man, dog, goat, monkey, anesthetized	Changes in arterio-venous pressure gradient under negative G: Animal / Initial Change / Later Change / Post-run Man / + / -30% / -65% Dog / - / -16% / -60% Goat / + / +65% / 0% Monkey / + / -12% / -40% Transient post-run cerebral ischemia except in goat. Later changes in arterio-venous gradient attributed to carotid sinus reflex activity or decrease in effective blood volume and failure of cardiac filling.	29,31
65		Goat, anesthetized	Arterio-venous (carotid-jugular) pressure difference reported by other investigators as decreased. When increased, arterio-venous gradient not greater than that sustained by normal vessels, and no cerebral hemorrhages found in absence of asphyxia or extraneous trauma.	13,29,34,35
66		Monkey; anesthetized	Cerebral circulation time increased 30% (photofluorographic technique); evidence for continued circulation at 12 negative G for 40 sec	33
67	Pulmonary circulation	Man, monkey	X ray with contrast media: increased opacity at lung apexes associated with fall in arterial O_2 saturation after several sec under negative G.	29

	Variable (A)	Animal (B)	Effect (C)	Reference (D)
	Negative (footward) Acceleration (concluded)			
	Blood flow (concluded)			
68	Renal circulation	Goat; anesthetized	Both arterial and venous renal pressures decrease.	16
69	Peripheral circulation	Man	Occlusive cuffs at thighs decrease venous pressure rise in frontal vein during negative G.	29
70		Dog; anesthetized	Petechial threshold. 11 negative G for 0.2 sec, 7 negative G for 1 sec, 3 negative G for 3-4 sec.	36
71		Goat; anesthetized	Boggy, pitting edema of head and neck (5 negative G for 5-10 sec), swelling of tongue, edema of pharynx and upper trachea which may lead to asphyxia; conjunctival, sinus, anterior eye chamber and middle ear hemorrhages.	29
72	Blood constituents	Goat, anesthetized	5 negative G for 15-30 sec post-run hematocrit peak = 118% of control, plasma protein peak = 107% of control, fluid loss = 15 ml/100 ml blood; protein loss = 1 g/100 ml blood; short rapid concentration phase followed by slower dilution phase.	35
73			Progressive stagnation of cerebral blood flow with repeated exposures as evidenced by anaerobic metabolic changes, such as initial elevation followed by depression of blood glucose, increased arterio-venous O_2 content difference (decreased venous O_2 content, constant arterial O_2 content); reduction in arterial and venous CO_2 content, increase in lactic acid and pyruvic acid content; increasing lactate-pyruvate ratio.	34
74		Monkey, anesthetized	Six animals, 12 negative G for 40 sec. arterial O_2 fell from 13 vol % to 6.1 vol %, venous O_2 (confluens sinuum) fell from 7.7 vol % to 2.4 vol %; arterio-venous O_2 difference not significantly changed; arterio-venous CO_2 difference not significantly changed.	33
	Respiratory effects			
75	Rate of breathing	Man	Slight increase.	26
76		Monkey, anesthetized	12 negative G for 40 sec apnea with sometimes incomplete inspiratory gasps.	33
77	Tidal volume	Man	Decreases.	26
78	Lung volume	Man	Decreases (measured at end-expiration).	26
79	Vital capacity	Man	Decreases.	26

Contributors. (a) Lawton, Richard W., and Herbert G. Shepler, (b) Bondurant, Stuart, and George D Zuidema

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93. HEMODYNAMIC EFFECTS OF IONIZING RADIATION. VERTEBRATES

Abbreviations and definitions: kv = kilovolt, a unit of electrical potential equal to 1000 volts; kvp = kilovolt peak, the crest value of the potential wave in kilovolts; mev = million electron volts, r = roentgen, the quantity of X or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign, rem = roentgen equivalent for man (or mammal), the absorbed dose equal to the dose in rads multiplied by the RBE; rad = rad unit, equivalent to 100 ergs/g energy absorption, RBE = relative biological effectiveness, i.e., the appropriate value of the biological effectiveness of the radiation in question relative to that of X radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received; rep = roentgen equivalent physical, equivalent to 93 ergs/g energy absorption; n = neutron, a nuclear particle of zero charge and mass number 1; mc = millicurie, the quantity of radionuclide disintegrating at the rate of 3.7×10^7 atoms per second, μc = microcurie, 3.7×10^4 disintegrations per second.

	Animal	Exposure or Administration	Type of Radiation	Dose	Accumulated Dosage or Exposure Time	Effect	Initial Symptom Manifestation[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Man	Entire body, single exposure (accident)	Mixed: X ray 80 kv equivalent r plus gamma	480 r 110 r		Decreased blood pressure. Tachycardia. Cardiac hypertrophy. Increased heart rate. Endocardial fibrosis and pericarditis.	24 hr 15th da 16th da 22nd da 24th da (last da of life)	1
2		Hands, single exposure (accident)	X ray 80 kv equivalent r	25,000-55,000 rem				
		Entire body, single exposure (accident)	Mixed: X ray 80 kv equivalent r plus gamma	1930 r 114 r		Hypotension. Circulatory collapse and myocardial hemorrhage.	14 hr 9th da (last da of life)	
3		Hands, single exposure (accident)	X ray 80 kv equivalent r	3,000-30,000 rem				
4		Entire body, single exposure (accident)	Mixed: X ray 80 kv equivalent r plus gamma	390 r 264 r		Temporary fall in blood pressure.	14 hr	
5		Entire body, single exposure (military)	Atomic bomb detonation (Japan, 1945)	Lethal		Epicardial hemorrhage, endocardial extravasation.	Terminal 3-6 wk	2
6		Entire body, single exposure (military)	Atomic bomb detonation (Japan, 1945)	Lethal		Epicardial petechiae, perivascular edema of coronary vessels. Myocardial hemorrhage.	1st wk 2 mo	3
7		Entire body, repeated exposure (therapy)	X ray 200 kv	10-25 r	40-100 r	Expansion of extracellular fluid, reduced intracellular fluid, increased interstitial fluid and plasma volume.		4
8		Thorax, repeated exposure (therapy)	X ray 250 kv		4500 r 52 da	Tachycardia.		5
		Thorax, repeated exposure (therapy)	X ray	175-250 r/da	7 da	Right heart failure, hypertrophy of right side of heart, pericarditis.	1-6 mo	6

9	Thorax, repeated exposure (therapy)	X ray	Intensive		T waves[2] lowered and inverted, myocardial degeneration.		7
10	Thorax, repeated exposure (therapy)	X ray	Intensive		Premature atrial and ventricular beats, myocardial degeneration.		8
11	Thorax, repeated exposure (therapy)	X ray 200 kvp	60 r	540 r 5 mo	Scarring of myocardium.	1 yr	9
12	Left upper quadrant of abdomen (therapy)	X ray 200 kvp		3000 r 25 da	Increased blood pressure, tachycardia, accentuated aortic second sound, telangiectasis of skin in irradiated site.	7 yr	10
13	Left renal region, repeated exposure (therapy)	X ray		3000 r 2 mo	Bounding pulse, increased blood pressure, malignant hypertension.	11 yr	11
14	Kidney region, repeated exposure (therapy)	X ray		4700 r 4 1/2 yr	Subendothelial proliferation of fibrous connective tissue in walls of medium and small renal arteries.		12
15	Kidney region, repeated exposure (therapy)	X ray		2300 r 3 wk	Hypertension.		13
16	Head, single and repeated exposure (therapy)	X ray 230 kv 250 kv		2300-10,500 r	Collagenous thickening, fibrinoid necrosis and thrombosis of smaller blood vessels of brain	9 mo-5 yr	14
					Sudden hypertension.		15
17	Tongue (therapy)	X ray	8250 r		Capillary dilatation.	6-24 hr	16
18	Skin (forearm), single exposure	X ray 200 kvp 50 kvp	300 r		Erythema.	Few hr	17
					Erythema.	8 da	
					Edema.	4 wk	
					Inflammation.	1 yr	
					Telangiectasis.		
19	Skin, single exposure	X ray	1000 r or more		Erythema.	1st da, 2nd-3rd wk, 4th wk	18
20	Skin, single exposure	X ray	400 r soft rays, 525 r medium rays, 600 r hard rays		Capillary proliferation and erythema.	6 hr	19
21	Skin, single exposure	X ray	1/2-1 skin unit dose		Dilated plexus vessels.	2nd da	20
22	Fingernail fold area, single exposure	X ray 130 kv	200 r		Hyperemia and erythema.	7th da	
			300 r		Erythema.	8th da	
23	Inhalation, repeated exposure (mining)	Radium	60 µg radium equivalent	3 yr	Fibrosis of media of pulmonary artery, myocardial degeneration.		21
24	Myocardium (accident)	Radium	2 mg	3 yr	Myocardial degeneration and necrosis.		22
25	Pelvis, repeated exposure (therapy)	Radium		1750-6000 mg/hr radium 4000 r X ray	Intimal plaques in myometrial arteries.		23
		X ray	600-1000 rad		Erythema.	24 hr and 1 mo	24
26	Skin, single exposure	Beta Strontium90	170-250 rep	2.5-5.25 min	Erythema.	48 hr	25
27	Forearm, single exposure	Beta P32	140 rep		Erythema.	3 wk	

/1/ Terminal refers here to period shortly before death when animal is moribund. /2/ Slow final wave of the ventricular complex resulting in restitution of the resting state in ventricles.

93. HEMODYNAMIC EFFECTS OF IONIZING RADIATION: VERTEBRATES (Continued)

	Animal	Exposure or Administration	Type of Radiation	Dose	Accumulated Dosage or Exposure Time	Effect	Initial Symptom Manifestation[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
28	Bat	Entire body, single exposure	X ray 250 kv	10,000-60,000 r		WBC adherence to endothelium, intravascular clumping of RBC, slowing of blood flow.		26
29		Wing, local, single exposure	X ray 50 kv	50,000-5,000,000 r		WBC adherence to endothelium, intravascular clumping of RBC, slowing of blood flow.		
30	Burro	Entire body, single exposure (external)	Gamma Zirconium95 Niobium95	500-900 r		Increased capillary fragility.	3-4 wk	27
31		Entire body, single exposure (external)	Gamma Tantalum182	200 r		Hemodilution.		28
				400 r		Hemoconcentration.		
32		Entire body, single exposure (external)	Gamma Tantalum182 Cobalt60	780 r (LD-50/30) 710 r (LD-50/30)		Venous pulsations, accelerated pulse rate (arterial).	Terminal	29
33		Entire body, repeated exposure (external)	Gamma Cobalt60	25 r/da	50-75 da	T wave[2] inversion, alteration of QRS complex[3], increased heart rate.		30
34	Cat	Abdomen, single exposure (under anesthesia)	X ray 260 kvp	5000 r		Increased carotid blood pressure.	10 min-2 hr	31
35		Thorax, abdomen, entire body, single exposure (under anesthesia)	X ray	Unfiltered X ray of medium hardness		Decreased carotid blood pressure, cardiac failure.	Within min	32
36	Dog	Entire body, single exposure	X ray 2 mev	600 r (LD-100/30)		Subepicardial petechiae, ecchymosis, hemorrhage, fibrosanguineous pericarditis.	Terminal	33
37		Entire body, single exposure	X ray 2 mev	1800 r		Dehydration.	3-4 da	34
						Vascular collapse.	Terminal	
38		Entire body, single exposure	X ray 2 mev	2000-3000 r		Increased heart rate, decreased blood pressure, hemoconcentration.	Terminal (3 da)	35
39		Entire body, single exposure	X ray 250 kvp	250 r, 500 r		Abnormal reactivity of isolated segments of carotid arteries.		36
40		Entire body, single exposure	X ray 250 kv	350 r		Increased capillary permeability.		37
41		Entire body, single exposure	X ray 250 kvp	350 r		Increased vascular fragility.		38
42		Entire body, single exposure	X ray 250 kv	450-550 r		Hemorrhage, plasma volume increased, total body water, blood volume decreased.	6-16 da	39
43		Entire body, single exposure	X ray 250 kv	Massive exposure		Diversion of RBC into lymph.		40

44	Entire body, single exposure	X ray 200 kvp	Lethal doses, 200-650 r (LD-50/30 = 315 r)		Increased heart rate	2 hr	41
					Plasma volume increased 14%, hemoconcentration, increased thiocyanate interstitial space	10 da	
					Decreased blood pressure, epicardial and myocardial hemorrhage.	Terminal	
					Increased PR interval[4], intravascular clumping of RBC, loss of plasma from vessels.		42
45	Entire body, single exposure	X ray 200 kvp	325 r		Increased blood volume.	Terminal	43
46	Entire body, single exposure	X ray 200 kvp	350-400 r		Plasma volume increased, decreased RBC mass.		44
47	Entire body, single exposure	X ray 200 kv	450-500 r		Plasma contained VDM (vasodepressor material), producing diminished vasomotion and sensitivity to epinephrine.	24 hr	45
48	Entire body, single exposure	Atomic detonation	Lethal		Increased extracellular fluid and plasma volume.	2nd da	46
49	Entire body, single exposure (splenectomized)	X ray	1000 r		Increased heart rate.	Terminal	42
50	Entire body, repeated exposure	X ray 200 kvp	25 r/da	30-200 da	Increased heart rate, plasma volume; decreased blood pressure; circulatory collapse; myocardial hemorrhage.	Terminal	47
51	Entire body, repeated exposure	X ray 200 kvp	12 5-50 r/da	880-1262 r	Atrial flutter and fibrillation, inversion of T wave[2], coronary vessel wall thickened, dilatation of right side, hydropericardium.		7
52	Anterior thoracic wall, repeated exposure	X ray 200 kv	5-19 HED (human erythema dose)	1-5 mo	Increased thickness of wall of right atrium, petechiae in right atrium.		48
53	Thorax, repeated exposure	X ray	Intensive		Hypertension, renal blood vessels thickened, endarteritis.		49
54	Abdomen, single exposure	X ray 200 kv	High voltage X rays	15-60 min	Hemoconcentration, shock.	60-72 hr	50,51
55	Abdomen, repeated exposure	X ray 130 kv		1400-2800 r	Circulatory failure.	96 hr	52
56	Heart, single exposure	X ray 180 kvp	1-3 HED (human erythema dose)		Perivascular bleeding, degeneration and atrophy of cardiac muscle fibers, hyalinization of pericardial connective tissue.		
57	Head, single exposure	X ray	Intensive		Degenerative changes in precapillaries and capillaries in brain.	6 wk	53
58	Entire body, single exposure (external)	Gamma Cobalt60	1300-1500 r		Dehydration.	3-4 da	34
					Vascular collapse.	Terminal	
59	Head	Gamma Cobalt60	1000 r		Decrease in frequency of cardiac contractions.		54

/1/ Terminal refers here to period shortly before death when animal is moribund. /2/ Slow final wave of the ventricular complex resulting in restitution of the resting state in ventricles. /3/ First downward wave, first upward wave, and second downward wave of the ventricular complex as indicated on an electrocardiographic tracing. /4/ Measurement from the beginning of the P wave to the beginning of the QRS complex and corresponding to the atrioventricular conduction.

93. HEMODYNAMIC EFFECTS OF IONIZING RADIATION: VERTEBRATES (Continued)

	Animal (A)	Exposure or Administration (B)	Type of Radiation (C)	Dose (D)	Accumulated Dosage or Exposure Time (E)	Effect (F)	Initial Symptom Manifestation[1] (G)	Reference (H)
28	Bat	Entire body, single exposure	X ray 250 kv	10,000-60,000 r		WBC adherence to endothelium, intravascular clumping of RBC, slowing of blood flow.		26
29		Wing, local, single exposure	X ray 50 kv	50,000-5,000,000 r		WBC adherence to endothelium, intravascular clumping of RBC, slowing of blood flow.		
30	Burro	Entire body, single exposure (external)	Gamma Zirconium^{95} Niobium^{95}	500-900 r		Increased capillary fragility.	3-4 wk	27
31		Entire body, single exposure (external)	Gamma Tantalum^{182}	200 r 400 r		Hemodilution. Hemoconcentration.		28
32		Entire body, single exposure (external)	Gamma Tantalum^{182} Cobalt^{60}	780 r (LD-50/30) 710 r (LD-50/30)		Venous pulsations, accelerated pulse rate (arterial).	Terminal	29
33		Entire body, repeated exposure (external)	Gamma Cobalt^{60}	25 r/da	50-75 da	T wave[2] inversion, alteration of QRS complex[3], increased heart rate.		30
34	Cat	Abdomen, single exposure (under anesthesia)	X ray 260 kvp	5000 r		Increased carotid blood pressure.	10 min-2 hr	31
35		Thorax, abdomen, entire body, single exposure (under anesthesia)	X ray	Unfiltered X ray of medium hardness		Decreased carotid blood pressure, cardiac failure.	Within min	32
36	Dog	Entire body, single exposure	X ray 2 mev	600 r (LD-100/30)		Subepicardial petechiae, ecchymosis, hemorrhage, fibrosanguineous pericarditis.	Terminal	33
37		Entire body, single exposure	X ray 2 mev	1800 r		Dehydration. Vascular collapse.	3-4 da Terminal	34
38		Entire body, single exposure	X ray 2 mev	2000-3000 r		Increased heart rate, decreased blood pressure, hemoconcentration.	Terminal (3 da)	35
39		Entire body, single exposure	X ray 250 kvp	250 r, 500 r		Abnormal reactivity of isolated segments of carotid arteries.		36
40		Entire body, single exposure	X ray 250 kv	350 r		Increased capillary permeability.		37
41		Entire body, single exposure	X ray 250 kvp	350 r		Increased vascular fragility.		38
42		Entire body, single exposure	X ray 250 kv	450-550 r		Hemorrhage, plasma volume increased, total body water, blood volume decreased.	6-16 da	39
43		Entire body, single exposure	X ray 250 kv	Massive exposure		Diversion of RBC into lymph.		40

74		Entire body, repeated exposure	X ray 200 kv	100 r at 35-da intervals	900 r total	Cardiac hemorrhage.		67
75		Entire body, single exposure (external)	Gamma Barium140 Lanthanum140	2500 r (1000 r/min)		Blood pressure depressed, then increased		68
76	Mouse	Entire body, single exposure	X ray 250 kvp	410 r		Increased amount of ground substance in tunica media of arteries.		69
77		Entire body, single exposure	X ray 250 kv	575 r (LD-50/30)		Decreased blood volume (plasma and cell), increased capillary permeability.	1-14 da	70,71
78		Entire body, single exposure	X ray 250 kv	575 r		Increased vascular fragility and capillary permeability.		72
						Decreased RBC mass.	3-17 da	73
79		Entire body, single exposure	X ray 250 kv	575 r		Decreased plasma volume.	1-10 da	74
						Blood perfusion through liver slowed.		
80		Intravenous, repeated injections	Beta Yttrium90	20,000-30,000 rep	3-9 da	Walls of blood vessels thinned.	24 hr	75
						Disappearance of tunica adventitia.	2 wk	
81		Total body surface, single exposure (external)	Beta Phosphorus32	5000 rep				76
						Inflammation of eyelids.		
				1.5-15 x 103 rep		Erythema on ears and feet.	10th da	
82		Total body surface, single exposure (external)	Beta Phosphorus32	4000 rep		Hyperemia.	4th wk	
						Swelling of myocardium.	6 hr	75
83		Intraperitoneal, single injection	Radium	1.0 µc/g of body weight		Hypotension, circulatory collapse.	80-160 min	77,78
84	Rabbit	Entire body, single exposure	X ray 260 kvp	630 r		Plasma volume decreased.	8th da	79
85		Entire body, single exposure	X ray 250 kvp	800 r fatal		Plasma volume increased.	Terminal 20th da	
				800 r non-fatal		Slight increase in plasma volume.	14th da	
86		Entire body, single exposure	X ray 250 kvp	1000 r		Increased vascular fragility and capillary permeability.		72
87		Entire body, single exposure	X ray 250 kvp	1000 r (LD-50/30)		Decreased blood volume, increased capillary permeability.	Immediate	70,71
88		Entire body, single exposure	X ray 250 kvp	1000 r		Decreased plasma volume followed by increase.	8-10 da	80
						RBC mass decreased.	3-17 da	
89		Entire body, single exposure	X ray 200 kvp	50-400 r		Decreased blood pressure followed by compensatory rise.	1-8 hr	81
						Transient decrease in blood pressure. Increased heart rate.	1-8 hr	
				600 r		Increased capillary permeability and number of patent blood vessels.	10th da	
						Peripheral vascular collapse.	Terminal	
90		Entire body, single exposure	X ray 200 kvp	800 r (LD-50/30)		Decreased peripheral circulation, constriction of peripheral blood vessels	35th da	82

/1/ Terminal refers here to period shortly *before death when animal is moribund.* /2/ Slow final wave of the ventricular complex resulting in *restitution* of the resting state *in ventricles.*

93. HEMODYNAMIC EFFECTS OF IONIZING RADIATION: VERTEBRATES (Continued)

	Animal	Exposure or Administration	Type of Radiation	Dose	Accumulated Dosage or Exposure Time	Effect	Initial Symptom Manifestation[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
60	Dog (concluded)	Intravenous, 3 injections	Colloidal gold	65,000 equivalent β r to liver	6 wk	Disappearance of endothelium, and marked increase in connective tissue surrounding hepatic blood vessels.	Terminal 62-119 da	55
61		Sino-atrial node implantation	Gamma Radon	0.6-5 mc	8 hr-8 mo	Engorgement and then rupture of wall of small vessels of region, occlusion of vasa vasorum, myocardial degeneration.		56
62		Intramuscular, single injection	Beta Strontium[89]	Lethal doses (LD-50/30 = 1.0 μc/g of body weight, or 0.5 μc/g of body weight retained dose for 10 da)		Increased plasma volume.		57
						Increased heart rate.	Terminal	
63		Intravenous, single injection	Alpha Plutonium[239]	Lethal dose (LD-50/30 = 0.3 μg/g of body weight)		Increased heart rate and plasma volume.	3-4 da before death	58
64		Entire body, repeated exposure	Neutron cyclotron		400 n over 4 da period	Decreased venous pressure; weak, rapid heart action; myocardial damage.	Terminal	59
65		Entire body, repeated exposure	Neutron	1.7 n/da	312 da	Myocardial hemorrhage.		60
66	Guinea pig	Entire body, single exposure	X ray 200 kv	2000 r		Bradycardia.		61
67		Entire body, head only or body with head shielded, single exposure	X ray 200 kv	50 r/min	25,000 r	Decreased heart rate, ventricular extrasystole, T wave[2] inversion.		62
68		Thorax, abdomen, entire body, single exposure	X ray	Unfiltered X ray of medium hardness		Decreased blood pressure, cardiac failure.	Within min	32
69	Hamster	Entire body, single exposure	X ray 130 kv	1000-1500 r		Bradycardia, vasoconstriction, T waves[2] depressed and inverted terminally.		63
70		Abdomen, single exposure	X ray 200 kvp	2000 r		Decreased blood volume.	3rd da	64
71		Cheek pouch implantation, repeated exposure	Beta Strontium[90]	140 μc		Increased vascularity, thrombo-embolism, petechiae, edema (of cheek pouch).	24 hr	65
72		Cheek pouch, single exposure	X ray	15,000-20,000 r		Increased vascularity, thrombo-embolism, petechiae.		
73	Monkey	Entire body, single exposure	X ray	400-500 r		Expanded plasma volume.		66

107	Rat	Entire body, single exposure	X ray 250 kvp	400-600 r		Plasma volume increased.	4-20 da	96
				750 r		Plasma volume decreased 20%, blood volume decreased 12%.	72 hr	
						Plasma and blood volumes increased 0-20%.	96 hr	
						Plasma volume increased 47%	10-20 da	
						Decreased blood pressure.	1-3 hr and 4-6 da	97
108		*Entire body*, single exposure	X ray 250 kvp	600 r		Vasodepressor material (VDM), decreased blood flow.	2nd da	98
109		Entire body or abdomen, single exposure	X ray 250 kvp	600 r		Peripheral vascular paralysis.	1st wk	
						Vasoexcitor material (VEM), increased blood flow.	2nd wk	
						Increased capillary permeability.		37
110		Entire body, single exposure	X ray 250 kvp	650-750 r		Diversion of RBC into lymph.	Immediate	40
111		Entire body, single exposure	X ray 250 kvp	Massive		Plasma volume decreased.	0-8 da	99
						Plasma volume increased	10th da	
112		Entire body, single exposure	X ray 220 kv	600 r (LD-50/30)		VDM - *vasodilatation*.	3,6,18 da	100
						VEM - vasoconstriction.	*10th da*	
113		Entire body, single exposure	X ray 200 kvp	600 r		Increased plasma volume and extracellular fluid, decreased intracellular fluid volume.	2nd and 20th da	101
114		*Entire* body, single exposure	X ray 200 kvp	700 r		Decreased blood and plasma volumes.	4-6 da	102
115		*Intestine* shielded, entire body, single exposure	X ray 200 kv	1000 r				
116		Entire body, *single* exposure	X ray 140 kv	700 r (LD-50/30)		Increased venous pressure.	3 hr and 5-12 da	103
						Decreased venous pressure.	2-4 da	
						Increased plasma volume.	3-12 hr	
						Decreased plasma volume.	12 hr-3 da	
						Decreased pulse rate.	*4-8 da*	
						Cardiac arrhythmia.	8-10 da	
						Cardiac failure.	Terminal[1]	
117		*Entire body, single exposure*	X ray 140 kv	700 r (LD-50/30)		Increased venous pressure, length and amplitude of 1st heart sound; *irregular heart beat; increase in height of* T wave[2].	12 hr and 5-12 da	104
						Increase in plasma volume.	6-10 da	
118		Entire body, anoxia, single exposure	X ray 250 kvp	*600-1400 r*		Hypertension.	3 mo-1 *yr*	105
119		Entire body, anoxia, single exposure	X ray 250 kvp	800 r		Hypertension.	1-1 1/2 yr	106
120		*Thorax*, single exposure	X ray 200 kv	1500 r		Pulmonary capillary engorgement.	8th da	107
				3000 r		"Flabby" myocardium.		
				7500 r		Round cell infiltration in myocardium, thickened coronary arteries.		
				10,000 r		Myocardial edema and congestion with capillary engorgement and hemorrhage, coronary bed dilated.		

/1/ *Terminal* refers here to period *shortly before death* when animal is moribund. /2/ *Slow* final wave of the ventricular complex resulting in restitution of the resting state in ventricles

93. HEMODYNAMIC EFFECTS OF IONIZING RADIATION: VERTEBRATES (Continued)

	Animal	Exposure or Administration	Type of Radiation	Dose	Accumulated Dosage or Exposure Time	Effect	Initial Symptom Manifestation[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
91	Rabbit (concluded)	Entire body, single exposure	X ray 180 kv	1250 r		Blood pressure fell after short period of fluctuation.		83
						Circulating blood volume decreased.	2 hr	
						Increased blood viscosity.	2-3 hr	
92		Entire body, single exposure (1 ear shielded)	X ray 250 kv	1500 r		Shielded ear: sludging of RBC. Unshielded ear: WBC adhered to endothelium, interstitial WBC exudation.		84
93		Abdominal skin, single exposure	X ray 20 kvp	6000 r		Blood pressure rose then fell during irradiation (later returned to normal).	Immediate	85
94		Localized small areas of skin on side and back, single exposure	X ray 86 kvp	680-2720 r		Capillary dilatation, increased capillary permeability.	1 hr	86
95		Head, single exposure	X ray 260 kvp	14,000 r (240 r/min)		Decreased blood pressure, circulatory collapse.	30 min	87
96		Head, single exposure	X ray 200 kvp	2850 r		Minute hemorrhage in walls of blood vessels of brain.	100 da	88
97		Ear, single exposure	X ray	10,000 r		Diffuse redness surrounding blood vessels in ear.	1 hr	89
						Erythema.	5 da	
98		Ear, single exposure	X ray 30 kv	1000 r		Erythema.	30 da	90
99		Thorax, single and repeated exposure	X ray	2000 r		Proliferation of connective tissue around coronary vessels, increased thickness of wall of right atrium, numerous petechiae in wall of right atrium.		48
100		Thorax, repeated exposure	X ray 200 kv 130 kv	600 r, 300 r 300 r at monthly intervals	1200 r	Zenker's necrosis in myocardium.	8-32 da after last exposure	91
101		Isolated ear, single exposure	X ray 260 kvp	1000-8000 r		Rate of blood flow decreased, then returned to normal.	Immediate but transient	92,93
102		Head, single exposure (external)	Gamma Cobalt^{60}	1000 r		Decrease in frequency of cardiac contractions.		54
103		Total body surface, single exposure (external)	Beta Phosphorus^{32}	1 3-25 x 10^3 rep		Inflammation of eyelids, erythema on ears and feet.	2nd wk	76
104		Skin, single exposure	Beta Phosphorus^{32}	1000 rep		Erythema.	6-10 da	94
105		Ear, single exposure	Beta Phosphorus^{32}	3000 rep		Erythema.	18 da	90
106		Skin of back, single exposure	Beta Phosphorus^{32}	5000 rep		Erythema.	3-5 da	95

137	Chick	Entire body, single exposure	X ray 200 kv	1000 r	<30 min	Hypotension.	Usually within 2 hr, always within 6 hr	120

/1/ Terminal refers here to period shortly before death when animal is moribund.

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93. HEMODYNAMIC EFFECTS OF IONIZING RADIATION: VERTEBRATES (Continued)

	Animal	Exposure or Administration	Type of Radiation	Dose	Accumulated Dosage or Exposure Time	Effect	Initial Symptom Manifestation[1]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Rat (concluded)	Thorax, single exposure (concluded)	X ray 200 kv (concluded)	20,000 r		Vacuoles in coronary arterial wall.	8th da	107
121		Thorax, single exposure	X ray 200 kv	1100 r		Congestion of coronary vessels.	10 da (sacrifice)	108
122		Thorax, single exposure	X ray 100 kv	700 r		Marked dilatation of right ventricle, congestion of myocardial capillaries, pyknosis of capillary endothelium.	1 wk (sacrifice)	109
123		Thorax, single exposure	X ray	10,000 r		Myocardial damage, degeneration of muscle fibers, intermuscular edema, capillary hemorrhage.	7th da	110,111
124		Thorax, repeated exposure	X ray 200 kv 130 kv	600 r, 300 r, 300 r at monthly intervals	1200 r	Zenker's necrosis of myocardium.	8-32 da after last exposure	91
125		Intravenous, single injection	Radium	270-5900 μc/kg of body weight		Arterial calcification.		112
126		Peritoneum	Radon ointment	200 μc/ml		Increased capillary fragility.		113
127		Head, single exposure	Radium applicator	14.63 mg Ra	3 hr	Blood vessels of brain engorged.		114
128		Intraperitoneal, single injection	Radium	0.5 μc/g of body weight		Degeneration of tunica adventitia.		75
129		Intravenous, single injection	Polonium	0.9-3.6 μc/kg of body weight		Myocardial hypertrophy and fibrosis.	375 da	115
130		Total body surface, single exposure	Beta Phosphorus^{32}	4000 rep		Inflammation of eyelids, erythema on ears and feet.	4th da	76
131		Abdominal skin, single exposure	Mixed. Strontium^{90} Phosphorus^{32}	90 rep/sec (Sr^{90}) 4500 rep/hr (P^{32})	28,000 rep	Inflammatory reaction in small arteries and veins of irradiated area.	10th da	116
132		Total body surface, repeated exposure	Beta Phosphorus^{32}	625 rep	2 mo	Early collapse and later disintegration of blood vessels.		75
133	Sheep	Anterior thoracic wall over heart, repeated exposure	X ray 200 kv	8-12 HED (human erythema dose)	1-5 mo	Hydropericardium, hyperemia of coronary vascular bed, dilatation of pericardial sac, heart distended.		7
134	Swine	Entire body, single exposure	X ray 2000 kvp	600 r		Degeneration of arterial endothelium.	50 min-164 hr (sacrifice)	117
135		Entire body, single exposure	X ray 1000 kvp	275 r (LD-50/30)		Dilatation of capillaries, impairment of circulation, hemostasis, increased capillary permeability, tissue anoxia.		118
				600 r		Enlarged right ventricle.	7th da (sacrifice)	
136		Entire body, single exposure	Atomic bomb source (gamma)	700 r		Cardiac dilatation.	7th da (sacrifice)	119

94. *EFFECT OF* IONIZING RADIATION ON HEMATOPOIETIC TISSUE VERTEBRATES

Abbreviations and definitions kv = kilovolt, a unit of electrical potential equal to 1000 volts, kvp = kilovolt peak, the crest value of the potential wave in kilovolts, *r* = *roentgen*, the quantity of X or gamma radiation such that the associated corpuscular emission 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign, n = neutron, a nuclear particle of zero charge and mass number 1; c = curie, the quantity of radionuclide disintegrating at the rate of 3.7 x 10^{10} atoms per second, mc = millicurie, 3.7 x 10^{7} disintegrations per second; μc = microcurie, 3.7 x 10^{4} disintegrations per second

	Animal	Tissue	Exposure or Administration	Type of Radiation	Dose	Effect	Initial Symptom Manifestation	Initiation of Recovery Following Exposure	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Man	Lymphoid tissue	Entire body, single exposure (Japanese *victims*)	Atom bomb	Lethal or sublethal doses	Atrophy	3 da (first examination).	5 da. (Initial attempt at recovery resulted in production of predominently atypical mononuclear cells.)	1
2		Bone *marrow*	Entire body, single exposure (Japanese victims)	Atom bomb	Lethal or sublethal doses	Decreased cellularity	Maximum decrease 6-30 da after exposure.	Some indication of recovery in all of survivors by 7 da.	1
						Proliferation of reticuloendothelium, increased reticulum cells, plasma cells, macrophages, and lymphocytes	6 da		
						Hyperplasia during recovery.	6 wk		
3		Bone marrow	Therapeutic atmosphere of 4 x 10^{-9} c/L of air, 1 hr per treatment	Radon	10 or more treatments	Erythroid hyperplasia, increased lymphocytes, decreased granulocytes, relative increase in basophil WBC in marrow.			2
4		Sternal bone marrow	Localized, therapeutic, single exposure	X ray 150-175 kv	100 r	Decreased erythroblasts.	2 da	Complete by 1 mo.	3
						Decreased myeloid cells.	3 da	Complete by 1 mo.	
5		Sternal bone *marrow*	Localized, therapeutic, single exposure	X ray 150-175 kv	200 r	Decreased erythroblasts.	2 da		3
						Decreased myeloid cells.	2 da		
						Decreased erythroblast mitosis.	2 da	4 da	
6		Sternal bone marrow	Localized, therapeutic, single exposure	X ray 150-175 kv	300 r	Decreased mitosis, erythroid cells, and myeloid cells.	1 da	1-2 mo	3
7		Sternal bone marrow	Localized, therapeutic, single exposure	X ray 150-175 kv	2000 r	Transient aplasia.			3
8		Sternal bone marrow	Localized, therapeutic, single exposure	X ray 150-175 kv	3000 r or more	Permanent aplasia.			3
9	Dog	*Bone* marrow	Entire body, single exposure	X ray 250 kvp	300 r	Decreased cellularity.	As early as 2 da after radiation.	24-28 da	4
						Decreased myeloid cells.	2 da	24 da	
						Decreased erythroid cells.	2 da	4 da	
						Reversed myeloid-erythroid ratio.	7-9 da	40 da	
10		Bone marrow	Intraperitoneal injection	$Gold^{198}$	244-504 mc	Marked decrease in all cellular elements of marrow.	Weeks		5

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23	Bone marrow	Intraperitoneal injection	Strontium89	2.0 µc	Decreased hematopoiesis (all cell series).	3 da	Sustained.	12
24	Lymph nodes and spleen	Entire body, single exposure	X ray 200 kvp	50 r	Occurrence of giant cells.	4 hr		8
					Increased debris in follicles.	4 hr		
					Necrotic foci in germinal follicles.	8-12 hr		
25	All lymphoid tissue	Entire body, single exposure	X ray 250 kvp	1/10 LD_{50}	Increased activity of adenosine triphosphatase and 5-nucleotidase.	Few hr	Few da	13
26	Lymph nodes	Entire body, single exposure	X ray 186 kv	400 r	Decreased cellularity.	2-3 hr	4 da	10
					Increased debris.	2-3 hr		
					Cytological damage.	2-3 hr	4 da	
					Disappearance of secondary nodules.	48 hr	7-14 da	
					Increased extramedullary myelopoiesis.	3-4 wk		
27	Lymph nodes	Entire body, single exposure	Fast neutrons (pile)	96 n	Complete destruction of nodules.	½ hr	3-9 da	7
28	Thymus	Entire body, single exposure	X ray or thermal neutrons plus γ	128-512 r	Induction of thymic lymphoma.	1 yr. (More common in females.)		14
29	Thymus	Entire body, single exposure	X ray or thermal neutrons plus γ	180 r	Involution.	3 da		15
30	Thymus and spleen	Entire body, single exposure	X ray	100-1000 r	Weight loss (proportional to dose).	120 hr		16
31	Spleen	Entire body, single exposure	X ray 186 kv	400 r	Decreased mitosis, lymphocytes, erythropoiesis; cytological damage.	2-3 hr	7-10 da	10
					Increased debris.	2-3 hr		
					Decreased megakaryocytes.	2-3 hr	10-14 da	
					Increased extramedullary myelopoiesis.	10 da		
32	Lymphoid elements of spleen	Entire body, single exposure	X ray 2000 kvp	625 r	Cellular injury (morphological).	1 hr	60 hr	17
33	Erythropoietic elements of spleen	Entire body, single exposure	X ray 2000 kvp	625 r	Cellular injury (morphological).	1 hr	66 hr	17
34	Myelopoietic elements of spleen	Entire body, single exposure	X ray 2000 kvp	625 r	Cellular injury (morphological).	Few days (subtle onset).	80 hr	17

94. EFFECT OF IONIZING RADIATION ON HEMATOPOIETIC TISSUE: VERTEBRATES (Continued)

	Animal	Tissue	Exposure or Administration	Type of Radiation	Dose	Effect	Initial Symptom Manifestation	Initiation of Recovery Following Exposure	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
11	Dog (concluded)	Regional lymph nodes	Interstitial injection into anterior chest wall	Gold^{198}	2 mc	Increased debris, decreased cellularity, abnormal mitosis, many abnormal plasmacytoid cells (predominant cell type).	3 da		6
12		Regional lymph nodes	Interstitial injection into anterior chest wall	Gold^{198}	2 mc	Congestion of sinusoids by large phagocytic mononuclear cells.	3 da		6
13		Regional lymph nodes	Interstitial injection into anterior chest wall	Gold^{198}	5-10 mc	Decreased cellularity, increased debris, areas of necrosis, many plasmacytoid cells, thrombonecrosis of blood vessels.	3 da		6
14			Interstitial injection into anterior chest wall	Gold^{198}	30-85 mc	Decreased cellularity, increased debris, necrosis of 90% or more of node, occasional islands of viable lymphoid tissues, numerous fibroblasts.	3-6 wk		6
						Dense scar tissue.	5-6 wk		
15	Guinea pig	Lymph nodes	Entire body, single exposure	X ray 200 kvp	175 r	Increased debris.	3 hr	24 hr	7
						Slight decrease in cellularity.	3-8 hr	4 da	
16	Mouse	Bone marrow	Entire body, single exposure	X ray 200 kvp	50 r	Increased heterophils.	3 hr	48 hr	8
						Increased myeloid cells.	8 hr		
						Increased myeloblasts.	12 hr		
17		Bone marrow	Entire body, single exposure	X ray 170 kvp	200 r	Visible chromosome aberrations.	18 hr		9
18		Bone marrow	Entire body, single exposure	X ray 200 kvp	350 r	Increased debris.	3 hr	5 da	7
						Decreased erythropoiesis.	3 hr	5-9 da	
						Decreased myelopoiesis.	3 hr	5 da	
19		Bone marrow	Entire body, single exposure	X ray 186 kv	400 r	Decreased lymphocytes.	1 da		10
						Decreased normoblasts, cellularity.	1 da	7 da	
						Decreased myelopoiesis.	2 da	7-14 da	
						Shift to left present in myelocytic series.	10 da		
20		Bone marrow	Entire body, single exposure	Mixed (detonation of nuclear device)	128 r	Threshold dose for induction of myelogenous leukemia.			11
21		Bone marrow	Entire body, single exposure	Fast neutrons (pile)	96 n	Increased debris.	3 hr		7
						Decreased cellularity.	3 hr	3 da	
22		Bone marrow	Entire body, single exposure	Fast neutrons (pile)	117 n	Cell death.	3 hr		7
						Decreased cellularity.	3 hr	5-9 da	
						Increased debris.	3 hr		
						Cytological damage, megakaryocytes.	1 da		
						Increased spindle cells.	9 da		

48		Spleen	Entire body, single exposure	X ray 200 kvp	800 r	Cytological damage (lymphocytes)	¼ hr		18
						Increased debris	¼ hr	8 hr	
						Destruction of lymphocytes	3 hr	9 da	
						Decreased cellularity.	3 hr	9 da	
						Increased plasma cells.	9 da		
						Decreased erythroblasts.	24 hr	14 da	
						Decreased myelocytes.	2 da	14 da	
						Decreased lymphocytes	15 min	12 da	
49	Rat	Bone marrow	Entire body, single exposure	X ray 200 kvp	550 r	Megakaryocytes.	3 hr	14 da	20
						Myeloid cells.	30-45 hr	14 da	
						Erythroid cells.	6-15 hr	5 da	
						Increased debris.	3 hr		
50		Bone marrow	Entire body, single exposure	X ray 200 kvp	600 r	Decreased erythropoiesis	3 hr	9 da	7
						Myelopoiesis.	2 da	31 da	
51		Bone marrow of irradiated leg	125-200 r/da to one leg	X ray 100 kv	1000 r in 8 da	Decreased cellularity, mitosis, M:E ratio[1]. Increased reticular cells, phagocytic cells; *relative increase* in nucleated RBC (absolute decrease).	1 da after last exposure (sacrificed).		21
52		Bone marrow of irradiated leg	125-200 r/da to one leg	X ray 100 kv	2500 r in 20 da	Almost no nucleated RBC remaining. Decreased cellularity, mitosis abolished, decreased M E ratio[1], increased reticular cells, increased phagocytes.	1 da after last exposure (sacrificed).		21
53		Bone marrow	*Single intra*venous	Polonium	50-170 μc/kg *of body* weight	Hypoplasia (extreme at 120-170 μc level, less severe at 50 μc level); hemorrhage.	At autopsy, 7-300 da (depending on dose).		22
54		*Bone* marrow	Single intravenous injection	Plutonium	300-3000 μc/kg of body weight	Hypoplasia (femoral distal epiphysis and vertebra).	At autopsy, 14-260 da (depending on dose).	Signs of active marrow regeneration in femoral shaft in rats *receiving lower* doses and surviving 30 da or more.	22
55		Bone marrow	Single intravenous injection	Radium	17-8000 μc/kg of body weight	Hypoplasia (femoral distal *epiphysis and vertebra*).	At autopsy, 11-407 da.		22
56		Bone marrow	Intraperitoneal injection	Radium	10-50 μg	Decreased megakaryocytes.	3 da	9 da	23
57		Bone *marrow*	Entire body, single exposure	Fast neutrons (cyclotron)	56.4 r	Decreased cellularity, mitosis, megakaryocytes, erythroid and myeloid cells.		16 da	24
58		Lymph nodes	Entire body, *single exposure*	X ray 240 kv	160 r	50% of lymphocytes *show nuclear* pyknosis.	5 hr		25
59		Lymph nodes	Entire body, single exposure	X ray 200 kvp	400 r	*Cytological* damage (lymphocytes), degeneration of nodule.	Within 16 hr.	3 da	7

/1/ In irradiated bone marrow, the myeloid cells were found to be greatly damaged and decreased in number, while the erythroblasts might be affected in the same way but to a lesser degree.

94. EFFECT OF IONIZING RADIATION ON HEMATOPOIETIC TISSUE: VERTEBRATES (Continued)

	Animal	Tissue	Exposure or Administration	Type of Radiation	Dose	Effect	Initial Symptom Manifestation	Initiation of Recovery Following Exposure	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
35	Mouse (concluded)	Spleen	Intraperitoneal injection	Strontium89	2.0 μc	Greatly increased erythropoiesis and megakaryocytopoiesis, decreased lymphocytopoiesis.	3 da	Sustained.	[illegible]
36	Rabbit	Bone marrow	Entire body, single exposure	X ray 200 kvp	100 r	Decreased mitosis.	Almost immediately after exposure.	3 hr	18
37		Bone marrow	Entire body, single exposure	X ray 200 kvp	400 r	Abnormal mitosis.	8 hr	14 hr	18
						Decreased mitosis.	3 hr		
						Decreased erythropoiesis.	3 hr	14 da	
						Decreased granulocytopoiesis.	1 da	Before 14 da.	
						Increased debris.	3 hr		
38		Bone marrow	Entire body, single exposure	X ray 200 kvp	800 r	Cessation of mitosis.	½ hr	10 da	18
						Decreased erythropoiesis.	½ hr	10-14 da	
						Increased debris.	3 hr		
						Decreased myelopoiesis.	1 da	14 da	
						Decreased megaloblasts.	2 da	21 da	
39		Lymph nodes	Entire body, single exposure	X ray 200 kvp	50 r	Increased debris.	3 hr	10 hr	18
40		Lymph nodes	Entire body, single exposure	X ray 200 kvp	100 r	Increased debris.	3 hr	24 hr	18
41		Lymph nodes	Entire body, single exposure	X ray 200 kvp	400 r	Increased debris.	Within 3 hr.		18
						Decreased cellularity of nodules.	3 hr	24 hr	
						Infiltration with heterophils.	1st da		
						Decreased mitosis.	3 hr	8 hr	
42		Lymph nodes	Entire body, single exposure	X ray 200 kvp	800 r	Shift to left in lymphocytes.	8-16 hr		18
						Decreased mitosis.	30 min	5 da	
						Destruction of lymphocytes.	30 min	5 da	
						Disappearance of nodules.	17-24 hr	21 da	
						Increased debris (rapidly removed by phagocytes).	30 min	17 hr	
43		Lymph nodes	Entire body, single exposure	X ray 200 kvp	800 r	Increased spindle cells (reticular cells).	24 hr		19
						Increased plasma cells.	9 da		
						Increased (infiltration by) heterophils (infiltration persists several da).	1 da		
44		Spleen	Entire body, single exposure	X ray 200 kvp	25 r	Increased debris.	1 da		18
45		Spleen	Entire body, single exposure	X ray 200 kvp	50 r	Cytological damage.	1 da		18
						Decreased mitosis.	1 da		
46		Spleen	Entire body, single exposure	X ray 200 kvp	600 r	Cytological damage.	1 da		18
						Cessation of mitosis.	1 hr	8 hr	
						Increased debris.	1 hr	8 hr	
						Cytological damage.	1 hr		
47		Spleen	Entire body, single exposure	X ray 200 kvp	800 r	Decreased cellularity.	1 hr	9 da	18
						Decreased size.	1 da		
						Cessation of mitosis.	½ hr	8 hr	

70		Lymphoid tissue	Entire body, single exposure	X ray 2000 kvp	600 r	Fragmentation of lymphocytes	50 min		26
						Increased nuclear debris.	50 min	3 hr	
						Increased phagocytosis of debris, infiltration of granulocytes.	3 hr		
						Destruction of almost all lymphocytes of central portion of nodules.	13 hr	36-45 hr (recovery very gradual).	
						Destruction of almost all lymphocytes of entire nodule (only reticular cells remain).	29 hr	36-45 hr	
71	Chick	Bone marrow	Entire body, single exposure	X ray 200 kvp	25 r	Cytological damage (lymphocytes).			27
72		Bone marrow	Entire body, single exposure	X ray 200 kvp	100 r	Decreased mitosis.	30 min	2 hr	27
						Decreased cellularity	13 hr	12 da	
73		Bone marrow	Entire body, single exposure	X ray 200 kvp	400 r	Decreased lymphocytes, myelocytes, erythroblasts.	7 hr	13-48 hr	27
74		Bone marrow	Entire body, single exposure	X ray 200 kvp	800 r	Decreased mitosis.	45 min		27
						Erythropoiesis abolished.	1 hr	2-4 da	
						Erythroblasts destroyed	1 hr	2-4 da	
						Granulocytopoiesis destroyed	14 hr		
						Small lymphocytes destroyed.	1-2 hr		
						Increased debris.	1-2 hr		
75		Spleen	Entire body, single exposure	X ray 200 kvp	25 r	Cytological damage (lymphocytes).			27
76		Spleen	Entire body, single exposure	X ray 200 kvp	100 r	Debris and dead lymphocytes.	½ hr	18 hr	27
77		Spleen	Entire body, single exposure	X ray 200 kvp	400 r	Decreased mitotic activity.	½ hr	7 hr	27
						Destruction of small lymphocytes.	½ hr	3 da	
						3/4 of small lymphocytes killed	4 hr	3-5 da	
78		Spleen	Entire body, single exposure	X ray 200 kvp	800 r	Cessation of mitosis.	45 min	5 hr	27
						Destruction of lymphocytes.	45 min	9 da	
						Increased hemocytoblasts.	45 min	1-3 da	
						Increased plasma cells.	2 hr		
79	Salmon	Kidney	Entire body, single exposure	X ray 200 kvp	500 r	Decreased hematopoietic cells in hematopoietic tissue.			28

Contributor: Ingram, Marylou

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94. EFFECT OF IONIZING RADIATION ON HEMATOPOIETIC TISSUE. VERTEBRATES (Concluded)

	Animal	Tissue	Exposure or Administration	Type of Radiation	Dose	Effect	Initial Symptom Manifestation	Initiation of Recovery Following Exposure	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
60	Rat (concluded)	Lymph nodes	Entire body, single exposure	X ray 200 kvp	600 r	Cytological damage (lymphocytes).	½ hr	14½ hr	7
						Degenerative change (nodules).	14½ hr	21 da	
						Disappearance of nodules.	24 hr	21 da	
						Infiltration with heterophils.	8 hr		
						Hemorrhage.	All periods up to 31 da.		
61		Lymph nodes	Single intravenous injection	Plutonium	300-3000 μc/kg body weight	Hypoplasia (more marked with greater doses).	At autopsy, 14-260 da.		22
62		Lymph nodes	Single intravenous injection	Radium	17-8000 μc/kg of body weight	Hypoplasia (more marked with higher doses), neoplastic changes in 3 of 20 rats examined.	At autopsy, 11-407 da.		22
63		Thymus, lymph nodes, and spleen	Entire body, single exposure	X ray 250 kvp	50-400 r (sublethal)	Increased activity of adenosine triphosphatase and 5-nucleotidase.	3 hr	72 hr	13
64		Spleen and lymph nodes	Single intravenous injection	Polonium	50-170 μc/kg of body weight	Extreme decrease in cellularity.	At autopsy, 7-300 da (depending on dose).		22
65		Spleen	Single intravenous injection	Plutonium	300-3000 μc/kg of body weight	Definite decrease in cellularity, hyperplasia of red pulp of spleen (extramedullary myelopoiesis).	At autopsy, 14-260 da.		22
66		Spleen	Single intravenous injection	Radium	17-8000 μc/kg of body weight	Complete or nearly complete atrophy of lymphoid elements at all dosage levels; extramedullary myelopoiesis more marked with higher doses.	At autopsy, 11-407 da.		22
67		Spleen	Entire body, single exposure	X ray 250 kvp	550 r	Increased debris.	30 min	8 hr	20
						Destruction of lymphocytes.	2 hr		
						Disappearance of nodules.	30 hr	15 da	
68		Spleen	Entire body, single exposure	X ray 200 kvp	600 r	Decreased cellularity.	2 hr	9 da	7
						Decreased megakaryocytes.	3 da	3 wk	
						Cytological damage (erythroblasts).	3 hr		
						Decreased erythropoiesis.	8 hr	9 da	
						Destruction of lymphocytes.	3 hr		
						Decreased mitosis.	½ hr	8 hr	
						Decreased cellularity of nodules.	3 hr	14 da	
69	Swine	Bone marrow	Entire body, single exposure	X ray 2000 kvp	600 r	Decreased erythroid elements.	9 hr	No evidence of regeneration during 164-hr period of observation.	26
						Destruction of virtually all nucleated red blood cells.	13 hr		
						Morphological damage to myeloid cells.	13 hr		
						Virtual absence of granulocytes	[illegible]		

7	Entire body, 5-10 r/da	X ray 200 kvp 400 kvp 1000 kvp	200-300 r	Decreased lymphocytes	Cancer patients with normal hematopoiesis.	5
8	Entire body, 5-20 r/da	X ray 200 kvp 400 kvp 1000 kvp	88-300 r	Decreased lymphocytes, neutrophils, WBC, RBC, hemoglobin.	Cancer patients with normal hematopoiesis.	5
9	Occupational, entire body, 0 2 r/wk	High energy gamma	77 wk	Decreased WBC, absolute lymphocytes, absolute neutrophils		6
10	Tumor therapy, 5-6 times/wk 1-50 megagram-r (integral doses), 3000-6000 r (tumor doses)	X ray 200 kvp 400 kvp	7 megagram-r	Reduced absolute lymphocyte count by 25%.	Increased injurious effect/megagram-r, with decreasing integral dose/da.	7
11	Therapeutic radiation, daily 50, 75, 100 r/da (30 x 30 cm or 45 x 45 cm fields)	X ray 250 kv	3-6 da	Transient increase in platelet count, followed by decrease.	Rate of decrease greater in patients with impaired hematopoiesis and greater with increased size of field.	8
12	Local irradiation of hands during fluoroscopy	X ray (portable machine) 55-60 kv	Approximately 800-1000 r (4 min) in 3 mo	Decreased absolute lymphocytes. Increased % lymphocytes on differential counts. Many abnormal monocytes	Normal when blood re-examined 6 mo later.	9
13	Occupational	Cyclotron workers	Approximately 3½ mo; probably below MPE (maximum permissible exposure)	Increased incidence of lymphocytes with bilobed nuclei. Picture returned to normal after extra shielding installed.		10
14	Experimental	20 radium workers 18 X-ray workers	Exposure not known, presumably daily	Persistent decrease in lymphocytes, less marked decrease in neutrophils (as compared with 40 controls)	Reported in 1921.	11
15	Occupational	Particle accelerator (predominantly X and γ rays)	Tolerance range approximately 200 mr/wk	Increased incidence of lymphocytes with bilobed nuclei.		12
16	Occupational	Radium, several hundred luminizers	Body burden less than 0 2 μg	Almost all workers showed presence of abnormal early mononuclear cells. These cells no longer present after individuals ceased luminizing	Examined each yr from 1941-1947.	13
17	Occupational	193 employees	0 05 r/da, 1943-1946	Increased refractile neutral red bodies in lymphocytes		14
18	Occupational	15 employees of radium institute	1 mo-23 yr	All showed "radiological blood picture," viz , high % of lymphocytes (relative lymphocytosis), normal RBC, and normal or high color index.	Studied in 1921.	15
19	Occupational	Employees of radium institute		All personnel showed counts differing very little from normal.	Studies made in 1923.	15

95. EFFECT OF IONIZING RADIATION ON PERIPHERAL BLOOD: VERTEBRATES

Part I: MAN

Abbreviations and definitions: kv = kilovolt, a unit of electrical potential equal to 1000 volts; kvp = kilovolt peak, the crest value of the potential wave in kilovolts; r = roentgen, the quantity of X or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electrical charge of either sign.

	Exposure or Administration (A)	Type of Radiation and/or Subject (B)	Accumulated Dosage or Exposure Time (C)	Effect (D)	Remarks (E)	Reference (F)
				Single Exposure		
1	Entire body (single or few closely-spaced exposures)	Atomic bomb detonation in Japan, 1945	Lethal and sublethal ("severe cases")	Rapidly developing leukopenia.	WBC virtually absent from blood of many of the fatally injured.	1
				Steadily decreasing RBC and hemoglobin.	Extremely severe anemia within 3-4 wk.	
				Decreased platelets.	Purpura and other hemorrhagic manifestations common.	
				Bizarre giant neutrophils, atypical lymphocytes, and occasional plasma cells.		
2	Entire body (single or few closely-spaced exposures)	Atomic bomb detonation in Japan, 1945	Sublethal (moderately severe and mild cases)	Leukopenia.	Minimal WBC during 4th wk. Lowest average WBC: 1500-2500/cu mm.	1
				Decreased RBC and hemoglobin.	Lowest RBC and hemoglobin levels 6-9 wk after exposure. Tendency towards macrocytosis.	
				Decreased platelets.		
				Increased eosinophils.	Definite increase in absolute eosinophil count 8-12 wk after exposure.	
3	Surface deposition, inhalation and ingestion	Fall-out from detonation of nuclear device	175 r (calculated)	Decreased lymphocytes.	Drop to 55% of control level by 3rd da after exposure. Remained stable at this level (greater depression in younger group).	2
				Decreased neutrophils.	Drop to 70-80% of control level by 2nd wk. Second decrease began 5th wk; counts fell to 50% of control level (greater depression in younger group).	
				Decreased platelets.	Minimum level (30% of control value) during 4th wk. Second depression during 7th and 8th wk.	
				Decreased hematocrit.	First measured on 22nd da.	
4	Head and neck	Dental X ray	35-315 r	Decreased absolute lymphocytes.	Observed during 12-hr post-exposure period.	3
5	Therapeutic dose to sacroiliac joints and spine	X ray 250 kv	300 r (mean surface dose)	Decreased lymphocytes, neutrophils, WBC, venous hematocrit.	Lymphocytes decreased 1-2 da after exposure, neutrophils 5th da (after temporary increase), WBC 2nd da, venous hematocrit 2nd da.	4
				Repeated Exposures		
6	Entire body, 15-20 r/dose	X ray 200 kvp 400 kvp 1000 kvp	60 r	Decreased lymphocytes.	Cancer patients with normal hematopoiesis.	5

31	Intravenous thorotrast containing 2 5 g thorium/12 ml solution (890 r/yr/g thorium), injected in 1931	Thorotrast	50 ml. Estimated total dose, 1780 *r/yr for* 25 yr	Chronic myelosis developed in *1954*, clinical course mild Paradoxical two-fold increase in WBC when spleen irradiated *with X rays*.	25-yr latent period	25
32	Single exposure	*Laboratory* accident	186 r of 80 kv X rays, plus 10 7 r y	Decreased absolute lymphocyte count	Duration, 1 yr.	26
				Increased refractile neutral red bodies in lymphocytes.	Present for 18 mo.	
33	Single exposure	Laboratory accident	*390 r of* 80 kv X rays, plus 26 4 r y	Decreased absolute lymphocytes. Increased *neutral* red bodies in lymphocytes	2 yr after exposure.	26
34	Entire body, single *exposure*, epilation	Hiroshima atomic bombing	Approximately 400 r	Slight decrease in % lymphocytes in peripheral blood.	1 yr later.	27
				Slight increase in eosinophils in peripheral blood.	1 yr later.	
				Greater variability in blood picture of the 904 *survivors than in blood picture* of matched control group.	1 yr later.	
35	Entire body	Fall-out after detonation of nuclear device in *Marshall* Islands (Rongelap), spring, 1954	175 r (calculated)	Decreased lymphocytes, monocytes, eosinophils, and platelets	1 yr after exposure (compared with carefully selected control groups).	28
36	Single exposure	Survivors of atomic bombing at Hiroshima, 1945		Increased incidence of leukemia among survivors at distance <2500 meters from impact.	Highest incidence among *those exposed* <1500 meters from impact. Peak incidence 1950-1952. More than 50% of cases acute or subacute (total number of cases, 92).	29
37	Single exposure, <1500 meters from impact	4 (of 5075) survivors of Nagasaki atomic bombing		*Refractory* (fatal) anemia characterized by leukopenia and thrombocytopenia.	Latent period, 4-7 yr.	30
38	Intravenous injection	Thorium X		Myeloid leukemia developed 1 yr after intravenous Thorium X for tuberculosis of knee joint.		31
39	Occupational	Probably X rays and radium	*Dosage not known,* exposure probably over many yr	Deaths due to leukemia 1.6 times higher among *physicians than among general* male population.		32
40	Occupational	Probably X rays and radium, dermatologists dying *between* 1935-1944	Dosage not known; exposure probably over many yr	Increased incidence of leukemia.		33
41	Occupational	X ray, physicians dying between 1938-1942	Dosage not known, exposure of long duration	Deaths due to leukemia 1.75 times greater among physicians than among general male population.	*Lower incidence* of death due to cancer in general.	34
42	Occupational	X ray, physicians generally, and radiologists	Dosage not known, repeated exposure	14 leukemia deaths/299 deaths in radiologists. 344 leukemic deaths/65,992 in physicians other than radiologists.		35

95. EFFECT OF IONIZING RADIATION ON *PERIPHERAL BLOOD*: VERTEBRATES (Continued)

Part I MAN (Continued)

	Exposure or Administration (A)	Type of Radiation and/or Subject (B)	Accumulated Dosage or Exposure Time (C)	Effect (D)	Remarks (E)	Reference (F)
				Repeated Exposures (concluded)		
20	Occupational	1405 employees in Institute of Radiophysics, Stockholm		Hypersegmentation of polymorphonuclear WBC nuclei, pathological lymphocytes, granulocytopenia, left shift in granulocytes	Study *reported in 1946.*	16
21	Occupational	Employees	0.02-0.05 r/da (estimated doses)	"In all probability, radiation quantities as low as 0.02-0.05 r/da can, after a comparatively short time, give rise to blood changes." Based on data from Nordenson (1946) and Helde (1946).		16-18
22	Experimental	Employees	125 megagram-r/wk	WBC lower than in controls and those receiving 100 mr/wk.		19
23	Experimental	Employees	100 megagram-r/wk	WBC lower than in controls.		19
24	Occupational	17 "new" radium workers	Few wk	12 of 17 showed definite depression of WBC, particularly neutrophils, with relative lymphocytosis and often a slight increase in eosinophils.	*Reported in 1935.*	20
25	Occupational	15 "old" radium workers	6 mo-3 yr	Blood picture same as that of new workers after several weeks.	Reported in 1935.	20
26	Occupational	Metallurgical laboratory workers: 205 worked 12 mo, 453 worked 6 mo	Less than 0.1 r/da	Showed significant increase in lymphocyte count after 6 and 12 mo of work.	Not statistically significant when compared with very slight lymphocyte increase in control group during same period.	21
27	Occupational	Radium luminizers	Body burden less than 0.2 μg	22-40% of workers examined showed relative lymphocytosis without neutropenia. Counts returned to normal after individuals ceased luminizing.	Several hundred individuals examined each yr from 1941-1947.	13
				Latent Effects		
28	Environmental	Adult population	Lifetime exposure	Leukemia 6 times more frequent among adults living on uraniferous terrain than among adults on neighboring, low-radioactive terrain		22
29	Occupational	X ray	Many years	Physician had mycosis fungoides for many years after working with X ray. Had "temporary leukemia" from time to time throughout 14-yr period.	"Temporary leukemia" (WBC approximately 33,000/cu mm, 90% lymphocytes), responded well to X-ray therapy.	23
30	Prenatal exposure during diagnostic X-ray examination of mother during pregnancy	X ray	Dose to fetal gonads frequently greater than 2.5 r	Increased incidence of leukemia in children of irradiated mothers.		24

Part II VERTEBRATES OTHER THAN MAN

Abbreviations and definitions kv = kilovolt, a unit of electrical potential equal to 1000 volts, kvp = *kilovolt peak*, the crest value of the potential wave in kilovolts, r = roentgen, the quantity of X or gamma radiation such that the associated corpuscular emission per 0 001293 g of air produces, *in air*, ions carrying one electrostatic unit of electrical charge of either sign, rad = rad unit, equivalent to 100 ergs/g energy absorption, n = neutron, a nuclear particle of zero charge and mass number 1, mc = millicurie, the quantity of radionuclide disintegrating at the rate of 3.7×10^7 atoms per second; µc = microcurie, $3\ 7 \times 10^4$ disintegrations per second

	Animal	Exposure or Administration	Type of Radiation	Accumulated Dosage or Exposure Time	Effect	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Bat	Entire body, single exposure (at room temperature)	X ray 250 kv	500 r	Decreased lymphocytes and granulocytes.	No decrease in RBC.	1
2	Burro	Entire body, 400 r/da	Cobalt60 gamma	10 da	Pronounced leukopenia (lymphocytes and granulocytes), decreased platelets, hyperferremia	Lymphocytes less than 8% of normal 1 hr after exposure. Minimal granulocyte count on 6th da	2
3	Dog	Entire body, single exposure	X ray 1000 kvp	5 r	Increased incidence of lymphocytes with bilobed nuclei for 4 wk.	Peak incidence 2nd and 3rd wk after exposure.	3
4		Entire body, single exposure	X ray 200 kvp	20 r	Decreased absolute lymphocytes.		4
5		Entire body, single exposure	X ray 200 kvp	50 r	Decreased absolute lymphocytes, platelets, WBC, granulocytes.		4
6		Entire body, single exposure	X ray 200 kvp	200 r	Decreased absolute lymphocytes, platelets, WBC, granulocytes, reticulocytes.	Decrease in WBC and platelets more marked with increasing dose to approximately LD_{100}.	4
7		Entire body, 0.5 r/da, 6 da/wk	X ray 200 kvp 1000 kvp	2 yr	Decreased lymphocytes.		5
8		Entire body, 1.0 r/da, 6 da/wk	X ray 200 kvp 1000 kvp	1 yr	Decreased lymphocytes, WBC, neutrophils.		5
9		Entire body, 3 r/da, 6 da/wk	X ray 250 kvp 1000 kvp	1-2 mo	Decreased absolute lymphocytes, reticulocytes, platelets.		5
10		Entire body, 6 r/da, 6 da/wk	X ray 250 kvp 1000 kvp	1-2 mo	Decreased WBC, absolute lymphocytes, absolute neutrophils, platelets.		5
11		Entire body, 10 r/da, 6 da/wk	X ray 200 kvp	1 mo	Decreased absolute lymphocytes, absolute neutrophils, WBC, hemoglobin, reticulocytes, RBC.		5
12		Entire body, 12 5 r/da	X ray 200 kvp	1278 r	Aplastic anemia. Drop in absolute lymphocytes to 700/cu mm.		6
13		Entire body, 25 r/da	X ray 200 kvp	900 r	Absolute lymphocytes reached level of 300/cu mm, severe anemia.		7
14		Entire body, 50 r/da	X ray 200 kvp	900 r	Absolute lymphocytes reached level of approximately 100/cu mm.		7

95. EFFECT OF IONIZING RADIATION ON PERIPHERAL BLOOD: VERTEBRATES (Continued)

Part I: MAN (Concluded)

	Exposure or Administration (A)	Type of Radiation and/or Subject (B)	Accumulated Dosage or Exposure Time (C)	Effect (D)	Remarks (E)	Reference (F)
				Latent Effects (concluded)		
43	Occupational	X ray, physicians dying during 1947-1951		Increased incidence of deaths due to leukemia.	Relatively short latent period (incidence increased within first 5 yr of exposure).	36
44	Therapy for ankylosing spondylitis (1940-1954)	X ray	Repeated exposure	Deaths due to leukemia 5-10 times expected number among patients receiving 1 course of therapy; at least 9 times expected number among patients receiving more than 1 course.	Some, but not all, of increased incidence may reflect increased susceptibility of patients with ankylosing spondylitis to leukemia.	37
45	Therapy for enlarged thymus	X ray, children, 1925-1951	50-1500 r	Doses less than 200 r associated with increased incidence of leukemia (larger doses with thyroid cancer).	Total incidence of neoplasms significantly higher among patients studied than among non-irradiated siblings.	38
46	X radiation of spine, therapeutic for ankylosing spondylitis	X ray	900-5950 r	7 patients: developed blood dyscrasias after therapy, 5 instances of myeloid leukemia (one had antecedent aplastic anemia), and 2 instances of aplastic anemia.	Latent period, 2¼ mo-6 yr.	39
47	Internal deposition	Chronic radium poisoning		Profound anemia and leukopenia. Fatal.	Hyperplastic marrow showing regeneration of megaloblastic type.	40

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32		Entire body, 4 4 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils.		15
33		Entire body, 4 4 r/da	Radium (gamma)	Approximately 1 yr	Decreased lymphocytes, WBC, heterophils, platelets, RBC, hemoglobin.		15
34		Entire body, 8.8 r/da	Radium (gamma)	10 da	Decreased lymphocytes, WBC.		15
35		Entire body, 8 8 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils, platelets.		15
36		Entire body, 8 8 r/da	Radium (gamma)	19 wk	Decreased lymphocytes, WBC, heterophils, RBC, hemoglobin (precipitous)		15
37	Hamster	Entire body, single exposure	X ray	600 r	Decreased lymphocytes, granulocytes, platelets, RBC, and hemoglobin.	Adhesiveness of WBC and platelets to endothelium not increased. RBC and hemoglobin decrease began about 9th da after exposure	16
38		Single exposure	X ray	825 r	Decreased granulocytes.	Maximum depression 5-7 da after exposure, returned to normal by 15th da.	17
39	Monkey	Entire body, single exposure	X ray 250 kv	50-100 r	Decreased lymphocytes, granulocytes, platelets, and RBC packed volume. WBC seldom <3000/cu mm.	Minimal levels about 15 da after exposure. Reached normal levels only after 30 or more da.	18
40		Entire body, single exposure	X ray 250 kv	260 r	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes	Minimal WBC 14-16 da after exposure. Marked reticulocytosis 16 da	19
41		Entire body, single exposure	X ray 250 kv	400 r	Decreased lymphocytes, granulocytes, platelets, RBC packed volume.	WBC remained between 400 and 1600/cu mm from 5-8 da after exposure; had not reached normal in 30 da.	18
42		Entire body, single exposure	X ray 250 kv	500-550 r	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes.	Rapid RBC decrease, with minimal levels 20-26 da after exposure. Reticulocytes absent 4th-17th da; reticulocytosis 18-29 da.	19
43		Entire body, single exposure	X ray 250 kv	600-650 r	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes.	Minimal RBC on 17th da. 4 survivors had RBC above normal levels by 100th da. Marked reticulocytosis and many circulating nucleated RBC after 18th da.	19
44		Entire body, single exposure	X ray 250 kv	800 r	Decreased lymphocytes, granulocytes, platelets, and RBC packed volume.	WBC at levels below 500/cu mm, 8th da after exposure. Recovery trend began on 15th da (no survivors after 17 da).	18
45		Single intramuscular injection	Strontium90 (in equilibrium with Yttrium90)	0.1-0.2 mc/kg of body weight	Decreased lymphocytes, granulocytes, platelets, and RBC.	Lymphocyte fall began immediately after injection; minimal WBC levels in 3rd wk.	20
46		Single intramuscular injection	Strontium90 (in equilibrium with Yttrium90)	0.47-0.5 mc/kg of body weight	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes.	Reticulocytes normal 11-15 da after exposure, reduced but not absent at 17-20 da. RBC decrease began 10th da after injection.	20

95. EFFECT OF IONIZING RADIATION ON PERIPHERAL BLOOD: VERTEBRATES (Continued)

Part II. VERTEBRATES OTHER THAN MAN (Continued)

	Animal	Exposure or Administration	Type of Radiation	Accumulated Dosage or Exposure Time	Effect	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
15	Dog (concluded)	100 r/wk	X ray 175 kv	Weeks	Decreased fragility of RBC in hypotonic saline and alloxan, except for sudden increase in fragility in terminal stage of X-ray sickness	Decreased fragility greater in splenectomized than in non-splenectomized dogs.	8
16		Entire body, 1.7 n/da, 6 da/wk	Fast neutrons	1 yr	Decreased WBC, absolute lymphocytes, absolute neutrophils, platelets, RBC.		9
17		Entire body, 1.7 n/da, 6 da/wk	Fast neutrons	3-4 wk	Decreased WBC, absolute lymphocytes, absolute neutrophils.		9
18		Repeated intraperitoneal injections	Gold198	244-504 mc	Decreased WBC.	Reached approximately 4800 WBC/cu mm; returned to normal 5-8 wk after initial injection.	10
19		Intravenous injection	Gold198	1 μc/kg of body weight	Moderate leukopenia, decreased hemoglobin and hematocrit, increased RBC sedimentation rate.	Hemoglobin and hematocrit depressed for several wk.	11
20		Intraperitoneal injection	Gold198	25.9-42.9 mc/kg of body weight	Definite leukopenia.	WBC in low normal range terminally.	10
21		Repeated intravenous injections	Gold198		Aplastic anemia.		10
22		Parenteral injection	Strontium89	2 or 7 mc	Decreased granulocytes, WBC, hematocrit.	Hematocrit depression greater with 7 mc, minimum level, 21-25 da.	12
23		Parenteral injection	Strontium89	20 mc	Decreased lymphocytes, granulocytes, WBC, hematocrit.	Hematocrit depression greater than that following 2 or 7 mc dose.	12
24	Goat	Entire body, single exposure	X ray 200 kvp	300 r	Decreased lymphocytes, neutrophils, WBC, RBC, hemoglobin.		13
25	Guinea pig	Entire body, single exposure	X ray 200 kv	220 r	Decreased all WBC, RBC, and hemoglobin.		14
26		Entire body, 0.11 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils.		15
27		Entire body, 1.1 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils.		15
28		Entire body, 1.1 r/da	Radium (gamma)	Approximately 1 yr	Decreased lymphocytes, WBC, heterophils; decreased platelets in females only.		15
29		Entire body, 2.2 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils.		15
30		Entire body, 2.2 r/da	Radium (gamma)	Approximately 1 yr	Decreased lymphocytes, WBC, heterophils, platelets.		15
31		Entire body, 2.2 r/da	Radium (gamma)	79 wk	Decreased lymphocytes, WBC, heterophils, RBC and hemoglobin decreased in males only.		15

32		Entire body, 4.4 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils.		15
33		Entire body, 4.4 r/da	Radium (gamma)	Approximately 1 yr	Decreased lymphocytes, WBC, heterophils, platelets, RBC, hemoglobin		15
34		Entire body, 8.8 r/da	Radium (gamma)	10 da	Decreased lymphocytes, WBC.		15
35		Entire body, 8.8 r/da	Radium (gamma)	Approximately 1 mo	Decreased lymphocytes, WBC, heterophils, platelets		15
36		Entire body, 8.8 r/da	Radium (gamma)	19 wk	Decreased lymphocytes, WBC, heterophils, RBC, hemoglobin (precipitous).		15
37	Hamster	Entire body, single exposure	X ray	600 r	Decreased lymphocytes, granulocytes, platelets, RBC, and hemoglobin.	Adhesiveness of WBC and platelets to endothelium not increased. RBC and hemoglobin decrease began about 9th da after exposure.	16
38		Single exposure	X ray	825 r	Decreased granulocytes.	Maximum depression 5-7 da after exposure, returned to normal by 15th da.	17
39	Monkey	Entire body, single exposure	X ray 250 kv	50-100 r	Decreased lymphocytes, granulocytes, platelets, and RBC packed volume. WBC seldom <3000/cu mm.	Minimal levels about 15 da after exposure. Reached normal levels only after 30 or more da.	18
40		Entire body, single exposure	X ray 250 kv	260 r	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes	Minimal WBC 14-16 da after exposure. Marked reticulocytosis 16 da.	19
41		Entire body, single exposure	X ray 250 kv	400 r	Decreased lymphocytes, granulocytes, platelets, RBC packed volume.	WBC remained between 400 and 1600/cu mm from 5-8 da after exposure; had not reached normal in 30 da.	18
42		Entire body, single exposure	X ray 250 kv	500-550 r	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes.	Rapid RBC decrease, with minimal levels 20-26 da after exposure. Reticulocytes absent 4th-17th da, reticulocytosis 18-29 da.	19
43		Entire body, single exposure	X ray 250 kv	600-650 r	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes.	Minimal RBC on 17th da; 4 survivors had RBC above normal levels by 100th da. Marked reticulocytosis and many circulating nucleated RBC after 18th da.	19
44		Entire body, single exposure	X ray 250 kv	800 r	Decreased lymphocytes, granulocytes, platelets, and RBC packed volume.	WBC at levels below 500/cu mm, 8th da after exposure. Recovery trend began on 15th da (no survivors after 17 da).	18
45		Single intramuscular injection	Strontium90 (in equilibrium with Yttrium90)	0.1-0.2 mc/kg of body weight	Decreased lymphocytes, granulocytes, platelets, and RBC.	Lymphocyte fall began immediately after injection; minimal WBC levels in 3rd wk.	20
46		Single intramuscular injection	Strontium90 (in equilibrium with Yttrium90)	0.47-0.5 mc/kg of body weight	Decreased lymphocytes, granulocytes, platelets, RBC, and reticulocytes.	Reticulocytes normal 11-15 da after exposure, reduced but not absent at 17-20 da. RBC decrease began 10th da after injection.	20

95. EFFECT OF IONIZING RADIATION ON PERIPHERAL BLOOD: VERTEBRATES (Continued)

Part II: VERTEBRATES OTHER THAN MAN (Continued)

	Animal	Exposure or Administration	Type of Radiation	Accumulated Dosage or Exposure Time	Effect	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
47	Mouse	Entire body, single exposure	X ray 200 kvp	50 r	Decreased lymphocytes, WBC.		21
48		Entire body, single exposure	X ray	50-250 r	Iron[59] uptake by RBC decreased.	Depression more marked with greater doses.	22
49		Single exposure	X ray 250 kvp	100-500 r	Increased incidence of leukemia.	After injection with virulent AK[4] leukemia cells, probit of % leukemic deaths plotted against log of dose in r gives regression line of type Y (= a + b log X).	22
50		Entire body, 1 or 2 exposures	X ray 250 kvp	119 rad	Increased incidence of myeloid leukemia.	More common in males; peak incidence, 6-15 mo of age.	23
51		1 or 2 exposures	Cyclotron, fast neutrons	110 rad	Increased incidence of myeloid leukemia.	More common in males; peak incidence, 10-14 mo of age.	23
52		Entire body, single exposure	X ray or thermal neutrons, plus γ rays (pile)	128 r or more	Increased incidence of myeloid leukemia. Necrosis of bone marrow in more than 50% of mice with myeloid leukemia.	Peak incidence, 12-16 mo of age.	24
53		Entire body, single exposure	Thermal neutrons, plus γ rays (pile)	80-min exposure, 3.3-4 3 x 10^{12} n/sq cm, plus 520 r γ	Decreased WBC, RBC, reticulocytes.	Recovery began after approximately 2 wk.	24
54		Entire body,[1] single exposure	X ray 140 kv	400-600 r	WBC decreased to same minimum level at same time (5-8 da after exposure) in both strains.	Recovery in both strains began 7-13 da after exposure.	25
55		Entire body,[2] 2.2 r/da	Radium (gamma)	29 wk	Decreased WBC, lymphocytes.		15
56		Entire body,[2] 4 4 r/da	Radium (gamma)	29 wk	Decreased WBC, lymphocytes.		15
57		Entire body,[2] 4 4 r/da	Radium (gamma)	79 wk	Decreased WBC, lymphocytes; decreased RBC, hemoglobin, platelets in males only.		15
58		Entire body,[2] 8 8 r/da	Radium (gamma)	29 wk	Decreased WBC, lymphocytes.		15
59		Entire body,[2] 8.8 r/da	Radium (gamma)	29 wk	Decreased WBC, lymphocytes, RBC, hemoglobin, platelets.		15
60		Entire body, 0.07 n/da, 5 da/wk	Fast neutrons (cyclotron)	30 n	Decreased WBC.		26
61		Entire body, 1 4 n/da, 5 da/wk	Fast neutrons (cyclotron)	230 n	Decreased absolute lymphocytes, WBC, RBC, hemoglobin. Increased frequency of WBC below 15,000/cu mm. Shift to left present in heterophils.		26
62		Intraperitoneal injection	Strontium[89]	0 068 μc/g of body weight	Decreased heterophils.	Effect seen in ABC male mice, not in CF-1 mice.	27

63		Intraperitoneal injection	Strontium89	0.068-14.5 µc/g of body weight	Decreased heterophils and lymphocytes.	Both cell types decreased about equally, decrease greater with greater doses	27
64		Intraperitoneal injection	Strontium89	2.0 µc/g of body weight	Sustained anemia in splenectomized mice only.	Sufficient myeloid metaplasia in spleen of non-splenectomized mice to prevent anemia.	27
65		Intravenous, intraperitoneal, or intracardial injection	Radium	0.02-0.03 µg	Decreased WBC.		28
66		Intravenous, intraperitoneal, or intracardial injection	Radium	0.1-0.2 µg	Macrocytic anemia.		28
67		Intravenous or intramuscular injection	Plutonium	0.0062 µc/g of body weight	Moderately severe decrease in WBC.	Effect sustained.	28
68		Intravenous or intramuscular injection	Plutonium	More than 0.0062 µc/g of body weight	Decreased WBC, platelets, and reticulocytes; anemia.		28
69	Rabbit	Entire body, single exposure	X ray 200 kvp	25 r	Decreased lymphocytes.	Return to normal by 48 hr after exposure.	6,29
70		Entire body, single exposure	X ray 200 kvp	100 r	Decreased lymphocytes, heterophils, reticulocytes, and platelets.	WBC depression tends to be greater and recovery slower with increasing doses.	30
71		Entire body, single exposure	X ray 200 kvp	200 r	Decreased lymphocytes, heterophils, platelets, reticulocytes, morphological abnormalities.	Increased neutral red granules in lymphocytes. Occasional phagocytic monocyte containing engulfed nuclear debris 12-24 hr after exposure.	30
72		Entire body, single exposure	X ray 200 kvp	500 r	Decreased WBC, platelets, reticulocytes, RBC, hemoglobin. Morphological abnormalities in leukocytes. Decreased WBC migration *in vitro*.	Anemia maximal on 14th da after exposure; RBC returned to normal by 23rd da.	30,31
73		Entire body, single exposure	X ray 200 kvp	800 r or more	Decreased lymphocytes, heterophils, reticulocytes, platelets, RBC, hemoglobin. Increased number of nucleated RBC.		30
74		Entire body, single exposure	Fast neutrons (pile)	9 n	Decreased absolute lymphocytes.		32
75		Entire body, single exposure	Fast neutrons (pile)	26 n	Decreased absolute lymphocytes, heterophils.		32
76		Entire body, single exposure	Fast neutrons (pile)	68-76 n	Decreased absolute lymphocytes, heterophils, platelets.		32
77		Entire body, single exposure	Fast neutrons (pile)	128 n	Decreased absolute lymphocytes, heterophils, platelets, RBC, hemoglobin, reticulocytes.		32
78		Entire body, 1.1 r/da (females only)	Radium (gamma)	Approximately 2 mo	Decreased absolute lymphocytes.		15
79		Entire body, 2.2 r/da (females only)	Radium (gamma)	Approximately 2 mo	Decreased absolute lymphocytes.		15

/1/ High and low WBC strains. /2/ LAF strain.

95. EFFECT OF IONIZING RADIATION ON PERIPHERAL BLOOD: VERTEBRATES (Continued)

Part II: VERTEBRATES OTHER THAN MAN (Continued)

	Animal	Exposure or Administration	Type of Radiation	Accumulated Dosage or Exposure Time	Effect	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
80	Rabbit (concluded)	Entire body, 2.2 r/da (females only)	Radium (gamma)	Approximately 9 mo	Decreased absolute lymphocytes, platelets.		15
81		Entire body, 4.4 r/da (females only)	Radium (gamma)	Approximately 2 mo	Decreased absolute lymphocytes.		15
82		Entire body, 4.4 r/da (females only)	Radium (gamma)	Approximately 9 mo	Decreased absolute lymphocytes, platelets.		15
83		Entire body, 8.8 r/da (females only)	Radium (gamma)	Approximately 2 mo	Decreased absolute lymphocytes.		15
84		Entire body, 8.8 r/da (females only)	Radium (gamma)	Approximately 9 mo	Decreased absolute lymphocytes, platelets.		15
85		Entire body, 1.7 n/da, 6 da/wk	Fast neutrons (cyclotron)	15-45 n	Decreased absolute lymphocytes, WBC.		9
86		Entire body, 1.7 n/da, 6 da/wk	Fast neutrons (cyclotron)	50-75 n	Decreased absolute lymphocytes, absolute neutrophils, WBC.		9
87		Entire body, 1.7 n/da, 6 da/wk	Fast neutrons (cyclotron)	325 n	Decreased absolute lymphocytes, absolute neutrophils, WBC, RBC, hemoglobin.		9
88		Entire body, 10 r/da, 6 da/wk	X ray 250 kvp 1000 kvp	60-120 r	Decreased absolute lymphocytes, absolute neutrophils, WBC.		5
89		Entire body, 10 r/da, 6 da/wk	X ray 250 kvp 1000 kvp	720-960 r	Decreased WBC, absolute lymphocytes, absolute neutrophils, RBC, platelets.		5
90		Intraperitoneal, intravenous, or intracardial injection	Radium	0.1 µg	Decreased WBC.		28
91		Intraperitoneal, intravenous, or intracardial injection	Radium	0.1-0.2 µg	Macrocytic anemia.		28
92		Intravenous or intramuscular injection	Plutonium	0.0062 µc/g of body weight	Decreased WBC.	Sustained	28
93		Intraperitoneal injection	$Strontium^{89}$	1.0 µc/g of body weight	Decreased heterophils.		28
94		Intraperitoneal injection	$Strontium^{89}$	3.0 µc/g of body weight	Decreased heterophils, lymphocytes, RBC, hemoglobin. Morphological changes in WBC and RBC.	RBC and hemoglobin returned quickly to normal.	27
95	Rat	Entire body, single exposure	X ray 250 kvp	5 r	Decreased absolute lymphocytes.		33
96		Entire body, single exposure	X ray 250 kvp	10 r	Decreased absolute lymphocytes, WBC.		33
97		Entire body, single exposure	X ray 250 kvp	50 r	Decreased neutrophils, WBC, absolute lymphocytes, reticulocytes.		33

98	Entire body, single exposure	X or gamma rays	2-75 r	Increased incidence of lymphocytes with bilobed nuclei.	Maximum incidence 1 wk after exposure.	34
99	Entire body, single exposure	X ray 200 kv	85 r	Lymphocytes decreased by 12th hr after exposure. Neutrophils increased transiently	Recovery began 2nd da after exposure. Approached normal in 4 wk.	35
100	Entire body, single exposure	X ray	5-100 r	Decreased Iron59 uptake by RBC.	Decrease more marked with greater doses.	36
101	Entire body, single exposure	X ray 250 kvp	100 r	Decreased absolute lymphocytes, neutrophils, WBC, reticulocytes, platelets		33
102	Entire body, single exposure	X ray 200 kv	175 r	Lymphocytes decreased by 4th hr. All WBC decreased after 24 hr.	Recovery approximately 12-16 da after exposure.	35
103	Entire body, single exposure	X ray	50-250 r	Decreased Iron59 uptake by RBC.	Depression varies as inverse function of radiation dose.	36
104	Entire body, single exposure	X ray 250 kvp	300 r	Decreased absolute lymphocytes, neutrophils, WBC, reticulocytes, platelets, RBC, hemoglobin.		33
105	Entire body, single exposure	X ray 200 kvp	600 r	Marked decrease in rate and extent of WBC migration in vitro 5 da after exposure.	Effect on WBC, not on plasma.	31
				Surface phagocytosis by WBC in vitro decreased 72 hr after exposure.	Returned to normal by 4th or 5th da after exposure.	
				Extracts of WBC obtained 3 da after exposure had lost bactericidal activity against test organism (Micrococcus aureus).		
106	Entire body, 0.5 r/da	X ray 250-1000 kvp	2 yr	Decreased absolute lymphocytes.		5
107	Entire body, 1 r/da	X ray 250-1000 kvp	1 yr	Decreased absolute lymphocytes.		5
108	Entire body, 1.7 n/da, 6 da/wk	Fast neutrons	1 mo	Decreased absolute lymphocytes.		9
109	Entire body, 1.7 n/da, 6 da/wk	Fast neutrons	1 yr	Decreased absolute lymphocytes, RBC, hemoglobin.		9
110	Single intraperitoneal injection	Phosphorus32	0.3-4.5 µc/g of body weight	Prompt leukopenia with minimum levels 12-14 da after exposure.	Minimum levels lower with greater doses. Rate of WBC decrease per r greater with smaller doses.	37
111	Single intravenous injection	Radium chloride	17 µc/kg of body weight	Decreased WBC, platelets (slight).	Lymphocyte depression more marked with greater doses. Neutrophils reached minimum level of only 4% of normal 14 da after 17 µc/kg.	38
112	Single intravenous injection	Radium chloride	300 µc/kg of body weight	Decreased WBC, platelets, anemia.	Spiking reticulocytosis 160 da after injection.	38
113	Single intravenous injection	Radium chloride	700 µc/kg of body weight	Decreased WBC, platelets, RBC, and reticulocytes.	Platelet depression maximum about 7 da after injection, then markedly elevated between 15-50 da.	38
114	Single intravenous injection	Plutonium citrate	18.9 µc/kg of body weight	Decreased lymphocytes, neutrophils, platelets.		38
115	Single intravenous injection	Plutonium citrate	47 µc/kg of body weight	Decreased WBC, platelets, RBC, hemoglobin.		38

Part II. VERTEBRATES OTHER THAN MAN (Concluded)

	Animal	Exposure or Administration	Type of Radiation	Accumulated Dosage or Exposure Time	Effect	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
116	Rat (concluded)	Single intravenous injection	Plutonium citrate	95 µc/kg of body weight	Decreased WBC, platelets, RBC, hemoglobin, reticulocytes.	With doses above 126 and 189 µc/kg, precipitous fall in RBC and hemoglobin suggests hemolytic process.	38
117		Radium, single intraperitoneal injection	Radium chloride	10-50 µg	Transient increase in platelets on 3rd da after injection, followed by progressive decrease.		39
118		Radium, parenteral injection	Radium chloride	0.02-0.03 µg	Decreased WBC.		28
119		Radium, parenteral injection	Radium chloride	0.1-0.2 µg	Macrocytic anemia.		28
120		Intravenous or intramuscular injection	Plutonium	0 0062 µc/g of body weight	Moderate, sustained WBC decrease.		28
121		Intravenous or intramuscular injection	Plutonium	More than 0.0063 µc/g of body weight	Decreased WBC, RBC, reticulocytes, platelets.	All decreases sustained.	28
122		Single intraperitoneal injection	Strontium89	0.22-0.25 µc/g of body weight	Decreased neutrophils.	More marked neutrophil decrease; also lymphopenia with higher doses.	27
123		Gavage	Yttrium91	10 µc/g of body weight	Transient decrease in absolute lymphocytes.		40
124		Gavage	Yttrium91	20 µc/g of body weight	Transient initial increase in RBC and hemoglobin followed by severe anemia; maximal 20 da after administration of Yttrium91.		40
125		Ingestion	Yttrium91	0.3-2.0 µc/g of body weight	Decreased lymphocytes; minimum levels at 90 da.	Prompt return to normal levels after Yttrium91 feeding discontinued.	40
126	Swine	Entire body, single exposure	X ray 1000 kv	200 r	Decreased WBC.		41
127		Entire body, single exposure	Nuclear explosion (Bikini tests)	Near lethal dose (survived 17 mo)	Macrocytic anemia.	One of two swine under observation also had achlorhydria.	42
128		Entire body, single exposure	Nuclear explosion (Bikini tests)	1300 r in 4-da period, or 1500 r in 5-da period	Decreased WBC and platelets. Many degenerative and abnormal WBC.	WBC less than 50% of normal on 4th da; platelets virtually absent on 9th da.	43
129	Chick	Entire body, single exposure	X ray 85 kv	360 r	Decreased lymphocytes.	Fully recovered from anemia in 4 wk; marked reticulocytosis 4 wk after exposure.	44
130		Entire body, single exposure	X ray 200 kvp	600 r	Decreased lymphocytes, heterophils, thrombocytes, RBC, hemoglobin, reticulocytes.		7

131		Intraperitoneal injection, 1 5 μc/g of body weight every 3 wk	Phosphorus32	Total dose, 4.5 μc/g of body weight	Anemia (most marked 28th post-injection wk).		45
132		Single subcutaneous injection[3]	Phosphorus32	235 μc	Decreased lymphocytes, WBC, and RBC.	Lymphocyte depression maximal on 4th da after injection, recovered slowly, reached normal on 55th da. RBC normal 41 da after injection.	46
133		Single subcutaneous injection[4]	Phosphorus32	300 μc	Fatal anemia.		47
134		Single subcutaneous injection[5]	Phosphorus32	760 μc	Fatal anemia.	760 μc in 28-da chick comparable to 300 μc in 19-da chick.	47
135	Salmon	Entire body, single exposure	X ray 200 kv	750 r	Decreased nucleated cells.		48

/3/ 6-da-old chick. /4/ 19-da-old chick. /5/ 28-da-old chick.

Contributor: Ingram, Marylou

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96. EFFECT OF IONIZING RADIATION ON BLOOD PRESSURE AND PULSE RATE: VERTEBRATES

Blood pressure values for man given as systolic/diastolic. Blood pressure values for other animals are mean arterial pressure, except in line 12. Method: *S = sphygmomanometer; H = saline-mercury manometer; G = strain gauge; P = plethysmograph.*

	Animal	No. of Subjects	Radiation and Dosage	Arterial Blood Pressure, mm Hg: Control	Time After Exposure, hr: 1-2	4	6	10-12	14-16	24-30	da: 2	4	8	13-20	Method	Pulse Rate, beats/min: Control	Time After Exposure, hr: 2-3	8	24	da: 4	8	13-15	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)	(W)
1	Man	1[2]	Accidental nuclear reaction[1]: 114 r γ, 1930 r X rays (soft)	120/78	110/70				100/65	120/65					S		104		95	85	130		1
2		1[2]	100 r γ, 480 r X rays (soft)	120/80	120/70					100/60	120/80			70/50	S		68		75	78	105	250	2
3		1	26.4 r γ, 390 r X rays (soft)	140/90	136/96				120/80		140/90			135/90	S				80	75	82	85	1
4		1	1 r γ, 31 r X rays (soft)	138/90	140/90						120/80				S		60						1
5		1	2.7 r γ, 42 r X rays (soft)		120/82					108/72					S								1
6		8	X ray therapy to chest region: 100-700 r (single exposure)	140/	124/	130/		133/	135/	140/					S	84	76						2
7		35	1,000-15,000 r (fractionated)[3]	149/							141/	134/	132/	130/	S								2
8	Dog	2	X ray, 300 r	117		122		105		103	92	100	78	90	H	88		97	84	90	130	150	3
9		1	α particles (Pu^{239}), 0.358 μg/g, intravenous	123										105	H	95			93	84	88	135	4
10	Rabbit	3-13	X ray, 800 r	99	58	64	74			70			84		H	198	298						5
11		4-11	X ray, 50-60 r	98	70	83	77			74	78	93	78	89	H								5
12		21	X ray, 630 r	109/66	58/28	64/34									G	282	282						6
13	Rat	7-8	X ray, 1500 r	95			73		67	59					H								7
14		5	X ray, 600 r	107	68	86									P								8
15	Chick, 3-4 da	5[4]	X ray, 1000 r	85	76	65	59								H								9
16		21[5]		85	67	36	24																
17	Pigeon	6-7	X ray, 2200-2400 r	138	141	137	147								H								10
18	Rooster	6-7[4]	X ray, 1200 r	150	117	108	108	120							H								11,12
19		13-17[6]		150	127	117	108	117															

/1/ Dosages given in equivalent terms of total body radiation. Some regions received extremely large amounts of radiations. /2/ Non-survivor at 30 days. /3/ 10-20 daily exposures. Blood pressure during therapy period. /4/ 24-hour survivors. /5/ Non-survivors at 10 hours. /6/ *Non-survivors at 24 hours.*

Contributor: Stearner, S. Phyllis

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97. EFFECT OF IONIZING RADIATION ON TOTAL BLOOD VOLUME AND PLASMA VOLUME: VERTEBRATES

Abbreviations TBV = total blood volume; PV = plasma volume; RBCM = red blood cell mass. Values for blood and plasma volume are in % of body weight.

	Animal	No of Subjects	Radiation and Dosage	Measurement	Control	Time After Exposure: hr 1-2	hr 4	hr 6	hr 16-24	hr 30-48	da 4	da 7	da 10-12	da 14-20	da 21-40	da Over 40	Method	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)
1	Dog	8	X ray, 200-400 r	TBV	9.1				9.6		8.7	9.0	9.1	8.6	9.4		PV: T-1824	1
2				PV	5.5				5.4		5.5	5.7	6.1	6.3	6.0			
3		6	X ray, 450-500 r	TBV	7.8						7.8	8.5	8.2	6.0			RBCM: P^{32}	2
4				PV	4.2						4.7	6.2	5.6	5.7				
5		1	a particles (Pu^{239}) 0.418 µg/g, intravenous	TBV	9.0								8.4				PV: T-1824	3
6				PV	5.3								6.0					
7		1	0.358 µg/g, intravenous	TBV	7.6								8.8					
8				PV	4.6								5.7					
9		1	0.287 µg/g, intravenous	TBV	9.2								10.7		8.4	8.9		
10				PV	5.1								7.9		6.7	7.8		
11	Mouse	7	X ray, 575 r	TBV	7.2						7.2		6.5	6.5			RBCM: P^{32}	4
12				PV	4.5[1]						4.6		4.7	4.9			PV: T-1824	
13	Rabbit	2	X ray, 1000 r	TBV	5.7				5.5		5.3	4.6	4.6	4.9	5.0		RBCM: P^{32}	4
14				PV	3.8[2]				3.9		3.5	3.0	3.2	3.7	3.8		PV: T-1824	
15		1-3	X ray, 800 r	TBV	5.7	5.2	6.8	5.1									PV: T-1824	5
16				PV	3.4	3.6	4.2	3.5										
17	Rat	7-8	X ray, 1500 r	TBV	7.0			6.7	5.6	5.2							RBCM: P^{32}	6
18				PV	3.4			3.5	3.2	3.0								
19		5	X ray, 750 r	TBV	4.6					4.8	5.2	4.7	4.5	4.8	4.8		RBCM: P^{32}	7
20				PV	2.5					2.4	2.8	3.1	3.7	3.5	3.9			
21		3-5	600 r	TBV	4.8					4.7	5.3	4.4	4.7	5.0				
22				PV	2.5					2.4	2.7	2.6	3.4	3.8				
23		4-5	400 r	TBV	4.8					4.8	5.2	4.5	5.1	4.5				
24				PV	2.5					2.6	2.8	2.7	3.2	3.0				
25		9-15	X ray, 700 r	PV	4.4					5.3				6.4	4.5		PV, T-1824	8
26		8-14	400 r	PV	4.4					4.5			4.4					
27		4-8	200 r	PV	4.4					4.2			4.5					
28	Chick	21	X ray, 1000 r	TBV	6.9		4.6										RBCM: Cr^{51}	9
29				PV	5.0		2.9										PV: I^{131}	
30	Rooster	29	X ray, 1200 r	TBV	5.9			4.8									RBCM: Cr^{51}	10
31				PV	3.4			2.2									PV: I^{131}	

/1/ Corrected for T-1824 removed from blood; factor = 1.2. /2/ Corrected for T-1824 removed from blood; factor = 1.08.

Contributor: Stearner, S. Phyllis

References: [1] Prosser, C. L., E. E. Painter, and M. N. Swift. 1956. In R. E. Zirkle, ed. Biological effects of external X and gamma radiation. Part 2, TID-5220. Dep. of Commerce, Office of Technical Services, Washington. pp. 1-99. [2] Soberman, R. J., R. P. Keating, and R. D. Maxwell. 1951. Am. J. Physiol. 164:450. [3] Painter, E. E., E. Russell, C. L. Prosser, M. N. Swift, W. Kisieleski, and G. Sacher. 1946. Clinical physiology of dogs injected with plutonium. USAECD-2042. Technical Information Service, Oak Ridge, Tenn. [4] Storey, R. H., L. Wish, and J. Furth. 1950. Proc. Soc. Exp. Biol., N. Y. 74:242. [5] Painter, E. E., C. L. Prosser, and M. C. Moore. 1956. In R. E. Zirkle, ed. Biological effects of external X and gamma radiation. Part 2, TID-5220. Dep. of Commerce, Office of Technical Services, Washington. pp. 147-181. [6] Montgomery, P. O., and S. Warren. 1951. Proc. Soc. Exp. Biol., N. Y. 77:803. [7] Supplee, H., J. D. Hauschildt, and C. Entenman. 1952. Am. J. Physiol. 169:483 [8] France, O. 1956. In R. E. Zirkle, ed. Biological effects of external X and gamma radiation. Part 2, TID-5220. Dep. of Commerce, Office of Technical Services, Washington. pp. 411-427. [9] Stearner, S. P., M. H. Sanderson, and E. J. Christian. 1956. Changes in organ blood volume in X-irradiated chicks. ANL-5696. Q. Rep. Biol. Med. Res. Div., Argonne National Laboratory. pp. 31-34. [10] Stearner, S. P., et al. 1957. Unpublished.

98. EFFECT OF IONIZING RADIATION ON ORGAN BLOOD VOLUME: CHICKEN

	Organ	Condition	Organ Weight g	RBC Mass[1] Active	RBC Mass[1] Inactive[2]	Plasma Volume	Method	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Chick[3]							
1	Liver	Control	1.69	7.4	4.0	15.7	RBC mass: Cr^{51}, P^{32}. Plasma volume: I^{131} human serum albumin	1
2		Irradiated[4]	1.52	3.6	9.2	7.2		
3	Spleen	Control	0.022	2.9	2.7	16.8		
4		Irradiated[4]	0.020	1.5	4.8	7.1		
5	Kidney	Control	0.245	7.9	1.2	24.7		
6		Irradiated[4]	0.259	5.2	7.5	9.4		
7	Lung	Control	0.210	17.1	2.1	40.3		
8		Irradiated[4]	0.217	18.0	2.1	20.9		
9	Proventriculus	Control	0.380	1.0	0	6.25		
10		Irradiated[4]	0.449	0.74	1.76	4.05		
11	Duodenum	Control	0.257	1.14	0.46	6.64		
12		Irradiated[4]	0.205	1.87	1.16	3.06		
13	Skeletal muscle	Control		0.91	0.19	2.85		
14		Irradiated[4]		0.94	0.31	1.70		
	Rooster[5]							
15	Liver	Control	56.84	19.4	7.1	34.8	RBC mass Cr^{51}. Plasma volume: I^{131} human serum albumin	2
16		Irradiated[6]	44.33	14.3	7.6	16.6		
17	Spleen	Control	4.68	16.5	6.4	22.1		
18		Irradiated[6]	1.79	6.5	12.7	8.4		
19	Kidney	Control	10.11	20.0	4.7	28.1		
20		Irradiated[6]	10.02	14.0	4.0	15.4		
21	Lung	Control	10.34	28.8	8.2	27.5		
22		Irradiated[6]	9.10	31.3	4.3	17.7		
23	Proventriculus	Control	4.44	2.63	0.03	6.80		
24		Irradiated[6]	4.91	1.64	0.15	3.80		
25	Duodenum	Control	3.69	2.86	0	7.40		
26		Irradiated[6]	3.53	2.83	0.12	4.10		
27	Skeletal muscle	Control		0.25	0.06	0.63		
28		Irradiated[6]		0.45	0.17	0.59		

/1/ % of total organ weight. /2/ RBC mass which is pooled or inactively circulating and does not contribute to the actively circulating RBC mass. /3/ 10 chicks, 3 to 4 days after hatching. /4/ 3-5 hours after irradiation with 1000 r X rays. /5/ 7-9 animals. /6/ 6-8 hours after irradiation with 1200 r X rays.

Contributor: Stearner, S. Phyllis

References: [1] Stearner, S. P., M. H. Sanderson, and E. J. Christian. 1956. Changes in organ blood volume in X-irradiated chicks. ANL-5696. Q. Rep. Biol. Med. Res. Div., Argonne National Laboratory. pp. 31-34.

[2] Stearner, S. P., et al. 1957. Unpublished.

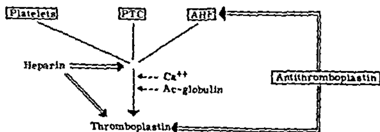
99. BLOOD COAGULATION

Differing theories for Stages II and III on the mechanics of blood coagulation are presented in Parts II and III, respectively.

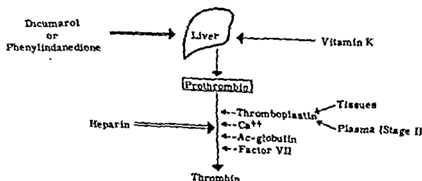
Part I: STAGES OF BLOOD COAGULATION (According to Monkhouse)

Synonymous terms for clotting factors: PTC (plasma thromboplastin component) = Christmas factor, platelet cofactor-2, autoprothrombin-2; AHF (antihemophilic factor) = antihemophilic globulin, thromboplastinogen; Ac-globulin = labile factor, factor V, proaccelerin; Factor VII = stable factor, autoprothrombin-1, proconvertin, cothromboplastin. Plasminogen = profibrinolysin; Plasmin = fibrinolysin. Symbols. ——→ gives rise to, - - - -→ acts on, ═══→ inhibits or destroys, [ ] present in blood.

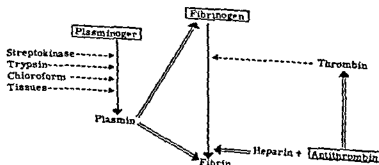
Stage I. Formation of Plasma Thromboplastin



Stage II. Formation of Thrombin



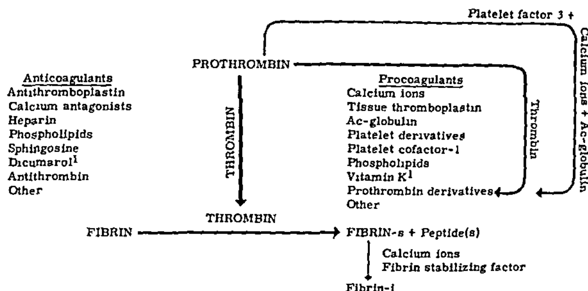
Stage III. Change of Fibrinogen to Fibrin



Contributor Monkhouse, Frank C.

Part II FORMATION OF THROMBIN (According to Seegers)

Prothrombin, which is regarded as being the only source of thrombin, is converted to thrombin by an enzyme also called thrombin. Substances that support the enzyme in this function are known as procoagulants and include derivatives of prothrombin. Substances that interfere with the activation of prothrombin, or of its derivatives, are known as anticoagulants. Fibrin-s is soluble in urea solution, whereas Fibrin-i is insoluble.

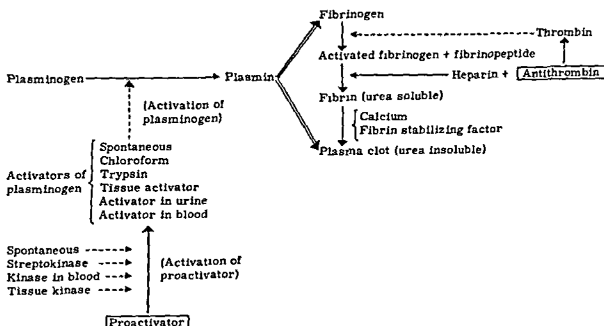


/1/ Related to prothrombin production.

Contributor: Seegers, Walter H.

Part III CHANGE OF FIBRINOGEN TO FIBRIN (According to Coon)

Symbols: ——→ gives rise to, - - - -→ acts on, ——→ inhibits or destroys, ▭ present in blood.



Contributor: Coon, William W.

References: [1] Lorand, L. 1954. Physiol. Rev. 34 742. [2] Sherry, S., et al. 1954. Ibid 34 736. [3] Astrup, T. 1956. Blood, N. Y. 11:781.

100. NATURAL-OCCURRING COAGULANTS AND ANTICOAGULANTS. PREPARATION AND ASSAY

For additional information on preparation and assay, see references 44-47.

	Substance (A)	Distribution (B)	Preparation: Method (C)	Preparation: Reference (D)	Assay: Method (E)	Assay: Reference (F)
1	Ac-globulin	Plasma, serum, platelets	From plasma, Ware and Seegers	1	Rate of formation of thrombin from purified prothrombin	1
			Lewis and Ware	2	Use of aged oxalated plasma	2
			From platelets, Ware, Fahey and Seegers	3	Thromboplastin generation test	29
			Adsorption on kaolin	4		
2	Antihemophilic factor	Fresh plasma	Fractional precipitation	5,6	Ability to promote prothrombin consumption in hemophilic plasma	6
3	Antithrombin	Plasma, in trace amounts, in the α-globulin fraction	Adsorption by aluminum hydroxide	7,8	Incubation with excess thrombin and calculation of thrombin remaining	7,27
4	Factor VII	Serum	Adsorption by $BaSO_4$ and elution	9,10	Acceleration of thrombin formation	10
5	Fibrinogen	Plasma, 120-470 mg %	Cold ethyl alcohol fractionation, salt fractionation, centrifugation of plasma at 0°C	11	Purity based on clottability (i.e., % clottable protein)	30
6	Heparin	Connective tissue generally; high level in liver of dog, ox, pig, and sheep, in lung of ox and skin of rat, associated with distribution of mast cells	Charles and Scott	12	On bases of anticoagulant potency:	
			Bell and Jaques	13	Whole blood	31,32
			Monkhouse	14,15	Recalcified blood	33
			Cass, Riley and West	16	Antithrombin potency	32
			Snellman, Jensen and Sylven	17	Metachromatic potency	34,35
					Combining power:	
					With protamine	36
					With toluidine blue	37
7	Heparin-cofactor	Plasma in the α-globulin fraction (may be identical to antithrombin)	Adsorption by aluminum hydroxide	7,8	Inhibits clotting of fibrinogen by thrombin in presence of heparin	7
8	Lipid anticoagulant	Blood, plasma	Cold methanol extraction	18,19	Inhibition of clotting time of recalcified plasma	38
					Activation of decalcified plasma by brain thromboplastin	19
9	Lipid antithromboplastin	Brain, spinal cord	Purified serine phosphatide fractions	20	Inhibits action of tissue thromboplastin, blocks formation of plasma thromboplastin	39
10	Plasma thromboplastin component (PTC)	Plasma and serum	Adsorption and elution	21	With PTC deficient blood	21
					Thromboplastin generation test	40
11	Plasminogen	Plasma	Ammonium sulfate precipitation	22	Lysis of standard clot	23
			Isoelectric precipitation and adsorption by kaolin	23	Digestion of casein	
12	Platelets and platelet fractions	Whole blood or lightly centrifuged plasma	Fractional centrifugation	24,25	For whole platelets, microscopic observations and counting; for fractions, specific for each material. (Not yet completely worked out.)	30
13	Prothrombin	Estimated 15 mg % in plasma	Acid precipitation from diluted plasma adsorbed by magnesium hydroxide and eluted with CO_2 under pressure	26	One-stage method	26,41
			Adsorption on barium citrate	2	Two-stage method	42
			Other methods	11		

	Substance	Distribution	Preparation		Assay	
			Method	Reference	Method	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
14	Thrombin	From prothrombin	Conversion of prothrombin with thromboplastin and calcium	27	According to its ability to clot fibrinogen	43
			Conversion with 25% citrate	28	Hydrolysis of p-toluenesulfonylarginine methyl ester	41

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101. *ORAL ANTICOAGULANTS*: MAN

All subjects, except those treated with Warfarin and Cumopyran Series II, had an initial basal *prothrombin* concentration of 70% or above. The major purpose for establishing this criterion was to create a uniform group of subjects with a *normal* coagulative response for the *proper* evaluation of therapeutic effectiveness. The same therapeutic range, 10-29% prothrombin concentration (21-45 seconds), was used in all groups, except for Warfarin in which a range of 10-35% was used. Prothrombin values in all groups were determined by the method of Quick [7]. Values in parentheses are ranges, estimate "c" (cf Introduction)

	Drug	No of Subjects	Dose mg: Effective Initial	Dose mg: Usual Maintenance	Dose mg: Corrective[1]	Achievement of Therapeutic Effect da	Subjects Achieving Therapeutic Effect[2] %: Within 24 hr	Within 48 hr	Within 72 hr	Average Recovery Time[3] da	Subjects with Prothrombin Escape: %	Duration, da	Subjects with Prothrombin Value <10% %	Incidence of Bleeding[4]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)
1	Dicumarol (3, 3'-Methylene-bis-4-hydroxycoumarin)	122	646	(25-125)	256	2.3	14	55	80	5	37	1.5	15	11% of 303 cases	1, b
2	*Tromexan* (3, 3'-Carboxy-methylene-*bis*-4-hydroxycoumarin)	50	(1500-1800)	(300-1200)	2100	2.1	12	82	96	2.5	90	1.8	20	9% of 100 cases	1, b
3	Warfarin (3-(α-Acetonyl-benzyl)-4-hydroxy-coumarin)	100	(40-50)	9.7(6.25-12.5)			23	75	85					5% of 100 cases	2, b
4	Liquamar (3-(1'-Phenylpropyl)-4-hydroxycoumarin)	100	(15-18)	(3-9)		2.0	25	90	92					5% of 100 cases	b
5	*Cumopyran* (3, 4-(2'-Methyl-2'-methoxy-4'-phenyl) pyranocoumarin) Series I	10	380	77(25-175)	135	2.1	0	50	100	3.3	58	1.4	15	8% of 13 cases	3
6	*Series II*	100					5	85	96		4		22	5% of 100 cases	4
7	Sintrom (*Nitrophenyl acetyl* ethyl-4-oxycoumarin)	52	58	(6-16)		2.3	2	60		1.5	81		27	17% of 70 cases	5
8	*Phenindione* (*2-Phenyl-1, 3-*indanedione)	133	685	130(25-200)	430	1.3	18	95	100	1.5	17	1.6	10	6% of 200 cases	1
9	Dipaxin (*2-*Diphenylacetyl-1, 3-indanedione)	64	63	9(2.5-15)	27	2.3	5	67	89	4.1	38	1.7	10	11% of 104 cases	6

/1/ Mean dose required to return prothrombin below 30% in those *subjects* with "prothrombin *escape*." /2/ Cumulative. /3/ For 40% recovery or better. /4/ All cases, *regardless of* initial prothrombin value.

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Anticoagulant dosage is usually determined in vitro from a coagulation time--the clotting time for heparin and heparinoid compounds, and the prothrombin time for indirect anticoagulants [4, 26-28]. However, this may not always correspond to the desired action in vivo [29], as the dosage required to prevent coagulation may be many times that indicated by the test in vitro.

Direct Anticoagulants: Heparin and heparinoid compounds, injected intravenously, give a prolonged coagulation time; for some purposes, the high peak blood levels resulting from this mode of administration are essential [2]. Heparin is inactive orally [30], and intramuscular and subcutaneous injections are not as generally effective as those given intravenously [b]. However, the subcutaneous route is the commonly accepted method of choice in doses of 75-100 mg, given each 8-12 hours (depending on the clotting time) [b]. It is desirable that the clotting time be approximately twice that of the normal control before the next dose is administered [b]. The effect on clotting time is increased and prolonged by caronamide [31] and phosphorylated hesperidin [32]. The value for maximum clotting time can be estimated from the effect of clotting time in vitro [3]. The international unit of heparin = the weight of 1/130 mg of international standard; commercial heparin = 90-120 units/mg.

Indirect Anticoagulants: These drugs are given orally. Dosage is dependent on the technique used to detect the change in prothrombin time and on individual susceptibility to the drug. A considerable number of individuals in some species are refractory to one or more of these drugs [11]. The effect on prothrombin time, which is cumulative, can be greatly enhanced by administering an initial dose followed by smaller repeated doses. Such administration also avoids toxic side effects. Dicumarol must be dissolved with a small amount of 5N sodium hydroxide for intravenous use. It can be given intraperitoneally in suspension in propylene glycol (10-100 mg/ml). Warfarin and Tromexan are more soluble than Dicumarol.

Values in parentheses are ranges, estimate "b" (cf. Introduction).

	Animal	Dose	Route	Maximum Clotting Time or Prothrombin Time		Achievement of Therapeutic Effect	Recovery Time	Remarks	Reference
				Control	Experimental				
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
					Heparin[1,2]				
1	Man	1000 units (10 mg)	IV		<4.5 min			28 hyporeactors.	1
2					4.5-7 min			50 normal reactors.	
3					>7 min			7 hyperreactors.	
4		5000 units	IV	15 min	115 min				
5		150 mg	IV		>80 min				
6		100 mg	IV		>80 min		4 hr	Incoagulable for 1 hr.	2
7		75 mg	IV		80 min		4 hr	Incoagulable for 1/2 hr.	
8		50 mg	IV		55 min		4 hr		
9		150 mg	IM	12 min	30 min		2 hr		
10		100 mg	IM	12 min	27 min		10 hr		
11		25, 50, 75 mg	IM	12 min	18 min	1 hr	6 hr		
12	Dog	30 units/kg	IV		34 min		3-4 hr		
13		100 units/kg	IV		>2 hr		32 min		
14		450 units/kg	SC		0.25-3.5 hr				3
15		2-3 units/kg/min for 2 hr	IV	20 sec	5 min		2-13 hr	Prolonged by anesthetics.	4
16		65-290 units/kg	IV	20 sec	5 min		4 hr	Thrombin time used. Heparin appeared in lymph in 10-90 min.	5
17	Rabbit	10.5 mg/kg[3] (50 units/kg)					200 min		
18		2.5 mg/kg					100 min	Duration proportional to dose.	6
19		1.0 mg/kg			>60 min				
20	Rat	1950 units/kg	SC		40 min		2 hr		7
21		5500 units/kg	SC		>24 hr		1 hr		
					>24 hr		6 hr	Normal in 12 hr.	8
							12 hr	Normal in 18 hr.	
					Dextran Sulfate				
22	Rabbit	21 mg/kg			>80 min		3 hr		7
23		17 mg/kg			>80 min		100 hr		
24		7 mg/kg			>80 min		50 min		

		Thrombocid (Xylan Polysulfuric Acid)							
25	Rabbit	30 mg/kg			>60 min		2.5 hr		7
26		15 mg/kg			65 min		1.5 hr	Minimum effective dose.	9
		Dicumarol (3, 3'-Methylene-bis-4-hydroxycoumarin)							
27	Man	300 mg			30 sec	3-4 da	Varies		10
28		250 mg			63 sec				
29		500 mg			106 sec		6 da		
30		750 mg		10.7(6.7-14.7) sec	37.8(30.4-45.2) sec			Quick prothrombin time.	11
31	Dog	5 mg/kg			No effect			Effective only with Vitamin K-deficient diet.	11
32	Hamster	5 mg/kg		10.6(7.8-13.4) sec	14.0(12.4-15.6) sec		24 hr	Quick prothrombin time.	11
33	Mouse	5 mg/kg		8.0(7.6-8.4) sec	25.4(8.4->60) sec		10 da	Quick prothrombin time.	11
34	Rabbit	5 mg/kg		8.0(7.6-8.4) sec	10.6(6.2-15.0) sec		5 da	Susceptibility decreased in puerperum.	10
35		2.5 mg		15-16 sec	27 sec	1 da	4 da		
36		10 mg/kg		15-16 sec	80 sec	1 da	5 da		
37		25 mg/kg		15-16 sec	6.5 min	2.5 da	8 da		
38		50 mg/kg		15-16 sec	20 min	3 da	8 da		
39		100 mg/kg		28 sec	32 sec	1 da	3 da	Susceptible animals only. 12.5% plasma prothrombin time.	12
40		0.37 mg		28 sec	40 sec	1-2/3 da	4-2/3 da		
41		0.75 mg		28 sec	46 sec	2 da	8 da		
42		1.5 mg		28 sec	67 sec	2.5 da	9 da		
43		3 mg		28 sec	85 sec	3 da	10 da		
44		6 mg		14.0(11.4-16.6) sec	19.9(18.7-21.1) sec		24 hr	Quick prothrombin time	11
45	Rat	5 mg/kg						Minimum effective dose.	13
46	Chicken	100 mg/kg						Effective dose.	14
47		300 mg/kg							
		Tromexan (3, 3'-Carboxymethylene-bis-4-hydroxycoumarin)							
48	Man	1200 mg		14 sec	25 sec	30 hr	56 hr		14
49		1200 mg		14 sec	32 sec	30 hr	60 hr		
50	Dog	10 mg/kg		15 sec	40 sec	2 da	5 da		15
51		40 mg/kg		15 sec	55 sec	3 da	5 da		
52	Rabbit	400 mg		12 sec	30 sec	30 hr	48 hr		14
53	Chicken	100-500 mg/kg						Minimum effective dose.	13
		Warfarin (3-(a-Acetonylbenzyl)-4-hydroxycoumarin)							
54	Man	45-50 mg initial		12 sec	28 sec			5-10 mg/da for maintenance.	16,b
55		100 mg	R		40 sec	18-24 hr	6 da		17
56	Rabbit	40 mg/kg	IP	9.6 sec	36.7 sec	48 hr			18
57		5 mg/kg	IP	7.9 sec	35.2 sec	48 hr			
58	Rat	0.03 mg/kg/da		25-36 sec	No effect				19
59		0.05 mg/kg/da		25-36 sec	55 sec				
60		0.10 mg/kg/da		25-36 sec	2 min				
		Liquamar (3-(1'-Phenylpropyl)-4-hydroxycoumarin)							
61	Man	18 mg		20.9 sec	40 sec	96 hr	144 hr		20
62		21 mg		20.9 sec	36 sec	96 hr	168 hr	Minimum effective dose.	13,20
63	Rabbit	2.5 mg		14 sec	22 sec	48 hr	96 hr		20
64		4 mg		14 sec	22 sec	72 hr	160 hr		
65	Chicken	50 mg/kg						Minimum effective dose.	13

/1/ Intra-arterial injection of 1 mg heparin/100 ml of blood, plus 1.2 mg protamine/100 ml of blood into venous outflow of organ (limb, kidney), gives satisfactory local heparinization without general heparinization in man and dog [24]. /2/ To neutralize heparin in man and dog, slowly inject protamine in the amount of 1.2-2.5 x weight of heparin in blood, as determined by in vitro titration; excess of protamine will be anticoagulant [8,24,25]. /3/ Crude heparin.

102. ANTICOAGULANTS IN VIVO: VERTEBRATES (Concluded)

	Animal	Dose	Route	Maximum Clotting Time or Prothrombin Time		Achievement of Therapeutic Effect	Recovery Time	Remarks	Reference
				Control	Experimental				
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	EDC (Ethylidene-bis-4-hydroxycoumarin)								
66	Man	0.5 g			Great individual variation			0.2 g maintenance dose.	21
67	Rabbit	20 mg	PO	7 sec	10 sec				
68		30 mg	PO	7 sec	27 sec				21
	Phenindione (2-Phenyl-1, 3-indanedione)								
69	Dog	50 mg/kg		9-13 sec	30 sec	26 hr	36 hr		22
70	Rabbit	50 mg/kg		10-12 sec	22 sec	25 hr	40 hr		22
	Dipaxin (2-Diphenylacetyl-1, 3-indanedione)								
71	Man	20 mg				1-2 da	6-10 da	2-4 mg maintenance dose.	23

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 EFFECT OF VITAMIN K_1 ON DICUMAROL-INDUCED HYPOPROTHROMBINEMIA: MAN

For effects of oral and intramuscular administration of water-soluble vitamin K_1, see reference 2. The object of small dose (0.5-2.5 mg) vitamin-K therapy is to bring an excessively prolonged prothrombin time back within the therapeutic range (25-45 seconds). Even such small doses may on occasion induce a response too great for maintaining a therapeutic level. In other instances, the dose administered may be too small to produce the desired effect. This dosage range, however, will not induce refractoriness to subsequent administration of anticoagulants; larger doses (50 mg and above) will occasionally induce refractoriness to tremendous doses of prothrombinopenic drugs for a period of several weeks. Values are calculated according to the Link-Shapiro modification of Quick's method: normal control = 15 ± 1 second; 30% = 25 seconds; 15% = 45 seconds. [3-5]

	Dose mg	Prothrombin Time, sec — Hours after Intravenous Injection of Vitamin K_1[1]												
		0	1	2	3	4	6	8	12	18	24	36	48	72
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)
1	0 5	106					45		31		29			
2		100			66		60		34	27				
3		95		70		63	56		59		56			
4	1.5	173			35		21							
5		76			55		42		31		26			
6	2 5	86			51		33		28					
7		61					25			18	14			
8		58		60		65	56	49			40			
9		40		39		26		22	20	18	18			
10	50 0	150		125		40	29		21	22		32	42	41[1]
11		130			29			24		19		17		
12		105				24	27			20		19	18	18
13		83	84		26		21		19	19	20		30	50[1]
14		54				28		20			19			
15		54				28		21			19			
16		46	45	42	32		22		19		18		17	19
17		38				22		18	18					
18		35				22		19	12		16			
19		33				21		15			17			
20		27				21		16			16			
21		540					29			21		16	19	25
22		59		29		25		19			16		17	17
23		49		30		23	19		17			16	16	

/1/ An occasional rebound in prothrombin time will occur in subjects receiving excessively high doses of anticoagulant and in patients with poor liver function. A second dose of vitamin K_1 is effective in correcting this response.

Contributor: Coon, William W.

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104. BLOOD COAGULATION TESTS, NORMAL VALUES: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Test	No. of Observations	Normal Value	Reference
	(A)	(B)	(C)	(D)
1	Two-tube clotting time	50	11.35(7.45-15.0) min	1
2	Two-tube silicone clotting time	54	22.51(14.3-31.0) min	1
	One-stage prothrombin test			
3	Quick	53	11.68(9.7-13.0) sec	2
4	Owren	48	29.06(19.5-35.0) sec	3
5	Ware	45	22.38(19.0-30.0) sec	4
6	Two-stage prothrombin test		356(290-425) units	5
7	Factor V	45	18.5(15.6-20.8) sec	6
	Factor VII			
8	Serum	37	21.0(19.4-24.0) sec	7
9	Plasma	40	25.3(22.2-27.4) sec	7
10	Prothrombin consumption	50	96.5(74-100) %	8
11	Thromboplastin generation	50	17.02(9.0-21.2) sec	9
12	Fibrinogen	57	273.5(120-470) mg %	10

Contributor: Coon, William W.

References: [1] Duff, I. F., R. H. Landaburu, J. Conrad, and J. A. Polhemus. Unpublished. [2] Quick, A. J. 1951. Physiology and pathology of hemostasis. Lea and Febiger, Philadelphia. [3] Owren, P. A. 1949. Scand. J. Clin. Lab. Invest. 1:81. [4] Ware, A. G., and R. Stragnell. 1952. Am. J. Clin. Path. 22:791. [5] Ware, A. G., and W. H. Seegers. 1949. Ibid. 19.471. [6] Wolf, P. 1953. J. Clin. Path., Lond. 6:34. [7] Tocantins, L. M. 1955. The coagulation of blood, methods of study. Grune and Stratton, New York. p. 144. [8] Quick, A. J. 1949. Blood, N. Y. 4:1281. [9] Biggs, R., and A. S. Douglas. 1953. J. Clin. Path., Lond. 6.23. [10] Ratnoff, O. D., and C. Menzie. 1951. J. Laborat. Clin. M. 37:316.

105. EFFECT OF HEPARIN AND HEPARINOID COMPOUNDS ADMINISTERED INTRAVENOUSLY: MAN

Hemorrhagic complications are considered as an extension of the therapeutic effect of the agent, rather than as a side effect. Injection of heparin and other heparinoid compounds contributes to a clearing effect on lipemic blood in man, resulting in a fall in serum triglycerides and a rise in serum fatty acids. [3]

	Drug	Dose	Effective Duration	Side Effect	Reference
	(A)	(B)	(C)	(D)	(E)
1	Heparin	50 mg	1 hr	Occasional transient alopecia.	1,2
2		75 mg	2 hr		
3		100 mg	2-3 hr		
4		150 mg	4-5 hr		
5	Paritol[1]	200 mg	2-3 hr	Nausea, vomiting, paresthesia, headache, vasomotor collapse; late development of alopecia. Increased [illegible]	3,4
6		300 mg	2-6 hr (highly [illegible]		
7	[illegible]	[illegible]	[illegible]	[illegible]	2,5
8	[illegible]	[illegible]	[illegible]	[illegible]	
9	[illegible] sulfate	[illegible]	[illegible]	[illegible] treatment prolonged beyond 3-5 da.	2,6-8

/1/ 11 major toxic reactions in 125 subjects receiving Paritol.

Contributor: Coon, William W.

References: [1] Duff, I. F., J. W. Linman, and R. Birch 1951. Surg. Gyn. Obst. 93:343. [2] Hirschboeck, J. S., F. W. Madison, and A. V. Pisciotta. 1954. Am. J. M. Sc. 227:279. [3] Shore, B., A. V. Nichols, and N. K. Freeman. 1953. Proc. Soc. Exp. Biol., N. Y. 83:216. [4] Duff, I. F. Unpublished. [5] Hodgson, P. E., and W. W. Coon. Unpublished. [6] Ricketts, C. R., K. W. Walton, B. D. Van Leuven, A. Birbeck, A. Brown, A. C. Kennedy, and C. C. Burt. 1953. Lancet, Lond. 2:1004. [7] Griffith, D. R., R. H. Landaburu, J. A. Polhemus, P. W. Willis, and I. F. Duff. Unpublished. [8] Jeavons, S. M., K. W. Walton, and C. R. Ricketts. 1956. Brit. M. J. 2.1016.

106. EFFECT OF HEPARIN ADMINISTERED SUBCUTANEOUSLY AND INTRAMUSCULARLY: MAN

	Heparin	Dose mg	Route	Achievement of Therapeutic Effect[1]	Time from Injection to Maximal Prolongation of Clotting Time	Time from Injection to Fall in Clotting Time below Therapeutic Level			Side Effects
						Minimal	Usual	Maximal	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Aqueous concentration	200	SC	2-4 hr	5-6 hr	4 hr	7-12 hr	16 hr	Rarely complete resistance; local pain, *tenderness*, ecchymoses.
2	In Pitkin menstruum	400[2]	IM	3-8 hr	19 hr	Frequently complete resistance	24 hr	31 hr	Frequently complete *resistance; local* pain, tenderness, hematoma
3	In gelatin-dextrose ("Depo-heparin")	400[3]	IM	2-6 hr	8-12 hr	16 hr	24 hr	30 hr	*Occasionally* complete resistance; local pain, tenderness, hematoma.
4		400[2]	IM	2-9 hr	8-12 hr	16 hr	16 hr	21 hr	

/1/ Twice normal clotting time. /2/ 200 mg with, and 200 mg without, vasoconstrictors. /3/ Without vasoconstrictors.

Contributor: Coon, William W.

Reference: [1] Duff, I. F., J. W. Linman, and R. Birch. 1951. Surg. Gyn. Obst. 93:343.

107. EFFECT OF COAGULANTS AND ANTICOAGULANTS ON CIRCULATORY FUNCTION: VERTEBRATES

	Drug	Animal and Dosage	[illegible]	[illegible]	[illegible]
	(A)	(B)	[illegible]	[illegible]	[illegible]
1	Fibrin (thrombin and fibrinogen)	Dog, rabbit, intr[illegible] cisternally	[illegible] pulmonary vein	[illegible]	[illegible]
2	Fibrinogen	Cat	Removed by *isolated* heart.		2
3	Fibrinopeptide (from iodinated fibrinogen)	Frog	Stimulated isolated heart.		3
4	Thrombin	Dog, intravenous drip	Fall in *systemic*, *rise* in pulmonary, blood pressure.	15-30 sec apnea, followed by dyspnea or sporadic gasping.	4
5		Rabbit, 10-100 mg/min, intravenously	Change in QRS, ST, T; random myocardial damage; bradycardia; arterio-venous dissociation.	Death in convulsions.	5
	Thromboplastin (present in crude tissue extracts)				
6	Brain extract	Dog, 0.2-0.3 g/kg	Shock. Clot in right heart and portal system.		6
7		Dog, 0.4-0.5 g/kg	Clot in right heart and portal system. Instant death.		
8		Dog, unanesthetized	Rise in blood pressure.	Abolished by heparin, cord section.	7
9		Dog, anesthetized	Marked, sustained fall in blood pressure.	Not abolished by cord section.	
10		Frog, brain trauma	Shock	Not abolished by cord section.	8
11	Lung extract	Dog	Fall in systemic, marked rise in pulmonary, blood pressure. Failure of peripheral pulse. Extreme cardiac dilatation.	15-30 sec apnea, followed by dyspnea or sporadic gasping. Death prevented by artificial respiration.	4

104. BLOOD COAGULATION TESTS, NORMAL VALUES: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Test (A)	No. of Observations (B)	Normal Value (C)	Reference (D)
1	Two-tube clotting time	50	11.35(7.45-15.0) min	1
2	Two-tube silicone clotting time	54	22.51(14.3-31.0) min	1
	One-stage prothrombin test			
3	Quick	53	11.68(9.7-13.0) sec	2
4	Owren	48	29.06(19.5-35.0) sec	3
5	Ware	45	22.38(19.0-30.0) sec	4
6	Two-stage prothrombin test		356(290-425) units	5
7	Factor V	45	18.5(15.6-20.8) sec	6
	Factor VII			
8	Serum	37	21.0(19.4-24.0) sec	7
9	Plasma	40	25.3(22.2-27.4) sec	7
10	Prothrombin consumption	50	96.5(74-100) %	8
11	Thromboplastin generation	50	17.02(9.0-21.2) sec	9
12	Fibrinogen	57	273.5(120-470) mg %	10

Contributor: Coon, William W.

References: [1] Duff, I. F., R. H. Landaburu, J. Conrad, and J. A. Polhemus. Unpublished. [2] Quick, A. J. 1951. Physiology and pathology of hemostasis. Lea and Febiger, Philadelphia. [3] Owren, P. A. 1949. Scand. J. Clin. Lab. Invest. 1:81. [4] Ware, A. G., and R. Stragnell. 1952. Am. J. Clin. Path. 22:791. [5] Ware, A. G., and W. H. Seegers. 1949. Ibid. 19:471. [6] Wolf, P. 1953. J. Clin. Path., Lond. 6:34. [7] Tocantins, L. M. 1955. The coagulation of blood, methods of study. Grune and Stratton, New York. p. 144. [8] Quick, A. J. 1949. Blood, N. Y. 4:1281. [9] Biggs, R., and A. S. Douglas. 1953. J. Clin. Path., Lond. 6:23. [10] Ratnoff, O. D., and C. Menzie. 1951. J. Laborat. Clin. M. 37:316.

105. EFFECT OF HEPARIN AND HEPARINOID COMPOUNDS ADMINISTERED INTRAVENOUSLY: MAN

Hemorrhagic complications are considered as an extension of the therapeutic effect of the agent, rather than as a side effect. Injection of heparin and other heparinoid compounds contributes to a clearing effect on lipemic blood in man, resulting in a fall in serum triglycerides and a rise in serum fatty acids. [3]

	Drug (A)	Dose (B)	Effective Duration (C)	Side Effect (D)	Reference (E)
1	Heparin	50 mg	1 hr	Occasional transient alopecia.	1,2
2		75 mg	2 hr		
3		100 mg	2-3 hr		
4		150 mg	4-5 hr		
5	Paritol[1]	200 mg	2-3 hr	Nausea, vomiting, paresthesia, headache, vasomotor collapse, late development of alopecia. Increased individual tolerance to repeated doses.	3,4
6		300 mg	2-6 hr (highly variable)		
7	Treburon	200 mg	2 hr	Prolonged administration resulted in high incidence of diarrhea and transient alopecia.	2,5
8		300 mg	2-3 hr		
9	Dextran sulfate	5000 units	1-3 hr	Transient alopecia. Marked cumulative effect when treatment prolonged beyond 3-5 da.	2,6-8

/1/ 11 major toxic reactions in 125 subjects receiving Paritol.

Contributor: Coon, William W.

References. [1] Duff, I F, J. W Linman, and R. Birch. 1951 Surg. Gyn. Obst 93 343. [2] Hirschboeck, J. S., F. W. Madison, and A. V. Pisciotta. 1954. Am J. M. Sc. 227 279. [3] Shore, B., A. V. Nichols, and N. K. Freeman. 1953. Proc Soc. Exp. Biol., N. Y. 83·216 [4] Duff, I. F. Unpublished. [5] Hodgson, P. E, and W. W. Coon. Unpublished. [6] Ricketts, C R., K. W Walton, B. D Van Leuven, A. Birbeck, A. Brown, A. C. Kennedy, and C. C. Burt. 1953. Lancet, Lond. 2 1004 [7] Griffith, D. R., R. H. Landaburu, J. A. Polhemus, P. W. Willis, and I. F. Duff. Unpublished. [8] Jeavons, S. M., K. W Walton, and C. R Ricketts 1956. Brit. M. J 2·1016.

106. EFFECT OF HEPARIN ADMINISTERED SUBCUTANEOUSLY AND INTRAMUSCULARLY. MAN

	Heparin	Dose mg	Route	Achievement of Therapeutic Effect[1]	Time from Injection to Maximal Prolongation of Clotting Time	Time from Injection to Fall in Clotting Time below Therapeutic Level: Minimal	Usual	Maximal	Side Effects
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Aqueous concentration	200	SC	2-4 hr	5-6 hr	4 hr	7-12 hr	16 hr	Rarely complete resistance; local pain, tenderness, ecchymoses.
2	In Pitkin menstruum	400[2]	IM	3-8 hr	19 hr	Frequently complete resistance	24 hr	31 hr	Frequently complete resistance, local pain, tenderness, hematoma.
3	In gelatin-dextrose ("Depo-heparin")	400[3]	IM	2-6 hr	8-12 hr	16 hr	24 hr	30 hr	Occasionally complete resistance; local pain, tenderness, hematoma.
4		400[2]	IM	2-9 hr	8-12 hr	16 hr	16 hr	21 hr	

/1/ Twice normal clotting time. /2/ 200 mg with, and 200 mg without, vasoconstrictors /3/ Without vasoconstrictors.

Contributor: Coon, William W

Reference [1] Duff, I. F., J. W. Linman, and R. Birch. 1951. Surg. Gyn. Obst. 93:343.

107. EFFECT OF COAGULANTS AND ANTICOAGULANTS ON CIRCULATORY FUNCTION, VERTEBRATES

	Drug	Animal and Dosage	Effect on Circulation	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)
1	Fibrin (thrombin and fibrinogen)	Dog, rabbit, intracisternally	Increased systemic and pulmonary blood pressure. Dilatation of left atrium and pulmonary vein.	Not blocked by vagotomy, *sympathectomy*; ganglionic blockade effective.	1
2	Fibrinogen	Cat	Removed by isolated heart.		2
3	Fibrinopeptide (from iodinated fibrinogen)	Frog	Stimulated isolated heart.		3
4	Thrombin	Dog, intravenous drip	Fall in systemic, rise in pulmonary, blood pressure.	15-30 sec apnea, followed by dyspnea or sporadic gasping.	4
5		Rabbit, 10-100 mg/min, intravenously	*Change in QRS, ST, T*, random myocardial damage; bradycardia; arterio-venous dissociation.	Death in convulsions	5
	Thromboplastin (present in crude tissue extracts)				
6	Brain extract	Dog, 0.2-0.3 g/kg	Shock. Clot in right heart and portal system.		6
7		Dog, 0.4-0.5 g/kg	Clot in right heart and portal system. Instant death		
8		Dog, unanesthetized	Rise in blood pressure.	Abolished by heparin, cord section.	7
9		Dog, anesthetized	Marked, sustained fall in blood pressure.	Not abolished by cord section.	
10		Frog, brain trauma	Shock	Not abolished by cord section.	8
11	Lung extract	Dog	Fall in systemic, marked rise in pulmonary, blood pressure. Failure of peripheral pulse. Extreme cardiac dilatation.	15-30 sec apnea, followed by dyspnea or sporadic gasping Death prevented by artificial respiration.	4

107. EFFECT OF COAGULANTS AND ANTICOAGULANTS ON CIRCULATORY FUNCTION: VERTEBRATES (Continued)

	Drug (A)	Animal and Dosage (B)	Effect on Circulation (C)	Remarks (D)	Reference (E)
	Thromboplastin (present in crude tissue extracts) (concluded)				
12	Kidney extract	Dog, bilaterally nephrectomized	Hemolytic necrosis of cerebral vascular walls.		9
13	Cephalin	Dog	No effect on blood pressure.		10
14		Frog	Antagonized calcium in isolated heart.		11
15	Kaolin	Dog	Same as for [illegible]	[illegible]	[illegible]
16	Agar	Dog	[illegible]	[illegible]	[illegible]
17	Russel viper venom (MgATP)	Cat, rabbit, rat	[illegible] nary vessels.	[illegible] vagotomy. Tachypnea.	[illegible]
18	Russel viper venom, asp venom, eel serum, cobra venom	Rabbit	Prevented fall in blood pressure.		13, 14
19	Plasmin (fibrinolysin)	Dog	No effect on hypertensin, oxytocin; destroyed vasopressin.		15
20		Dog, guinea pig	Decreased blood pressure.	Due to another plasma protein in fibrinolysin preparations.	16
21		Turtle	Decreased output of isolated heart.		
22	Trypsin	Dog, 13,000 units/kg	Transient drop to 40 mm Hg in blood pressure. Caused intravascular clotting.		17
23		Dog, 25,000 units/kg	Caused intravascular clotting. Death in 15-45 min.		
24		Rabbit	Clotting and symptoms same as for thrombin and thromboplastin (see above).		18
25		Rabbit, 0.2-1.0 mg/min	Change in P, QRS, ST, T; arterio-venous dissociation, random myocardial damage.		5
26	Vitamin K, dietary deficiency of	Mouse, rat, on sulfaguanidine	Myocardial lesions. Hemorrhage necrosis, leucocytic infiltration.		19
27	Menadione (K_3)	Dog, 2-10 mg/kg	Decrease in blood pressure. No effect on blood vessels.	Arrested isolated heart, 1:10^5. Negative inotropic action, 1:10^6 to 1:10^7. No effect on action of adrenalin, ephedrine, amphetamine, acetylcholine.	20, 21
28		Dog, 50 mg/kg	Hypotension, then hypertension and death. No effect on vessels.		
29	K_3 diphosphate sodium	Dog, 2 mg/kg	No effect on blood pressure or vessels.		
30	K_3 disuccinate	Dog, 2 mg/kg	No effect on blood pressure or vessels.		
31	K_3 diacetate	Dog, 2 mg/kg	Lowered blood pressure. No effect on vessels.		
32	K_3 bisulfite sodium	Dog, 2 mg/kg	Lowered blood pressure. No effect on vessels.		
33	Platelets, purified bovine	Dog	Marked increase in pulmonic and systemic blood pressure.		22
34	Antiplatelet serum	Dog	Hypotension, shock.	Histamine liberated.	23
35	Heparin (commercial solutions containing tricresol)	Man	No effect on coronary dilator. ECG changes in standard exercise test.		24
36		Cat, dog	No effect on retrograde blood flow in vessels.		25
37		Dog	No effect on blood pressure.	No respiratory effect.	13, 26
38		Dog, 10 mg/kg	Sodium salt increased coronary flow, barium salt had no effect on flow.		27
39		Hamster	Increased blood flow in venules.		28

107. EFFECT OF COAGULANTS AND ANTICOAGULANTS ON CIRCULATORY FUNCTION: VERTEBRATES (Continued)

	Drug (A)	Animal and Dosage (B)	Effect on Circulation (C)	Remarks (D)	Reference (E)
40	Heparin (commercial solutions containing tricresol) (concluded)	Rabbit, 1:10,000	Decreased coronary flow of isolated heart.		29
41		Rabbit, <1:10,000	No effect on heart.		
42		Frog	Initial inhibition of perfused isolated heart	Due to dialyzable materials in commercial heparin.	30
43	Heparin and other mucopolysaccharides	Rat	Arrest of vasomotion.	Reversed action of adrenalin.	31
44	Heparin	Man	No effect on claudication time.		32
45		Man	No effect on heart effort in angina.		33
46		Man, hypertensive	Fall in blood pressure to normal levels.	Blood pressure fall accompanied by urinary excretion of histamine.	34, 35
47		Man, atherosclerotic	Increased forearm arteriovenous O_2 difference in 60% of subjects.		36
48		Dog	Heparin fixed to cement substance in blood vessels		37
49		Dog, ischemic compression shock	No effect on blood pressure.		38
50		Dog, adrenal chloroform syncope	Prevented intracardiac thrombosis without preventing syncope		39
51		Rat, hypertensive, with DOCA, 100 units/kg, subcutaneously	Fall in blood pressure to normal levels.	Duration of effect shortened by pretreatment with 48/80, or water intraperitoneally to disrupt mast cells.	40-42
52		Rat, hypertensive, by renal encapsulation	Fall in blood pressure to normal levels.	Effect prevented by antihistamines.	
53	Heparin, plus ergotamine tartrate	Rat	No effect on gangrene.		43
54	Xylan sulfuric acid ester	Rabbit, 2.5-50 mg/kg	Fall in blood pressure.	Respiratory effects secondary to blood pressure changes.	44
55		Rabbit, 80 mg/kg	Death.		
56	Cellulose sulfuric acid ester	Rabbit, 3 mg/kg	Death.		44
57	Liquoid (Sodium polyanethol sulfuric acid)	Cat	Transitory fall in blood pressure with increase in venous pressure, often failure to return to initial blood pressure.		26, 45
58		Rabbit	Intracapillary precipitates		26, 45
59	Novirudin	Cat	Decrease in systolic blood pressure. Decrease in minute volume.		26
60		Rabbit	Hypertension for 2-6 min.		26
61	Chlorazol fast pink	Cat, dog	No effect on blood pressure		26
62		Guinea pig, rabbit	Marked fall in blood pressure		26
	Protamines				
63	Salmine	Cat, 5 mg/kg	Transitory fall in blood pressure.		46
64		Dog, 5 mg/kg	Marked fall in blood pressure when injected rapidly. Vasodilator in muscles	Blood pressure effect blocked by removal of platelets and modified by cord section.	46
65		Guinea pig, 5 mg/kg	Slow fall in blood pressure, death.		47
66		Rabbit, 5 mg/kg	Slight rise in blood pressure.		46
67	Salmine, clupeine	Rat, 20-30 mg	Collapse		48

107. EFFECT OF COAGULANTS AND ANTICOAGULANTS ON CIRCULATORY FUNCTION: VERTEBRATES (Continued)

	Drug (A)	Animal and Dosage (B)	Effect on Circulation (C)	Remarks (D)	Reference (E)
	Protamines (concluded)				
68	Clupeine	Dog, 50-100 mg/kg	Marked fall in blood pressure when injected rapidly. Vasodilator in muscles.		47, 49
69		Guinea pig, rat, 100 mg/kg	Lethal occlusion of blood vessels.		50
70		Rabbit, 15 mg/kg	50% reduction in vascular flow in isolated ear.		51
71		Rabbit, 20 mg/kg	Reduced coronary flow of isolated heart 50%. Complete constriction of medial artery of ear.		
72		Frog, 0.5-5.0 µg	Increased action of acetylcholine on heart. Increased capillary permeability.	Displaced platelets and serum proteins from capillary endothelium.	52, 53
73		Frog, 20 µg	Strengthened isolated hypodynamic heart. Increased capillary permeability.		
74		Frog, 50 µg	Increased capillary permeability. Stopped heart.		
75	Toluidine blue, azure A	Dog, rabbit, 1-10 mg/kg	Slight increase in blood pressure. Bradycardia. Increase in T wave and high take off of P. No effect on heart response to acetylcholine or epinephrine. Vasoconstriction of blood vessels in hind leg of dog.	Higher dose required for cardiac effects after atropine. Increased respiratory rate and depth of breathing.	54
76		Rabbit, isolated heart	No effect on transmission, cytotoxic effect.		55
77		Frog, isolated heart	Cholinergic blockade.		55
78	Dicumarol	Man	No effect on normal or abnormal ECG.		56
79			No effect on ECG with standard exercise tests.		24
80		Man, arteriosclerotic	Slight reduction in extremity blood flow (plethysmograph).		57
81		Dog	Increased coronary flow.		45
82		Rabbit, 5-20 mg/kg	Momentary slight rise in blood pressure. 0.25% caused inhibition of isolated heart. Perfusion of peripheral vein, contraction, large doses caused dilatation.	No effect on respiration.	58, 59
83		Rabbit, 10 mg/kg	Pronounced engorgement of great veins.		60
84	Dicumarol, plus ergotamine	Rat	No effect on gangrene.		43
85	Dicumarol (also 4 hydroxycoumarin and indanediones)	Cat, rabbit, 10-50 mg/kg	Usually decreased, sometimes increased, blood pressure.	Rapid rise in O_2 consumption, respiratory rate and amplitude. Effects on O_2 consumption; increased by vitamin K_3, not by K_1.	61
86	2-isovaleryl-1, 3-indanedione	Cat, 5-60 mg/kg	Decline in blood pressure. Rapid vasodilation (direct).	Increase in depth of breathing.	62

Contributor: Jaques, Louis B.

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	Drug (A)	Animal and Dosage (B)	Effect on Circulation (C)	Remarks (D)	Reference (E)
	Protamines (concluded)				
68	Clupeine	Dog, 50-100 mg/kg	Marked fall in blood pressure when injected rapidly. Vasodilator in muscles.		47,49
69		Guinea pig, rat, 100 mg/kg	Lethal occlusion of blood vessels.		50
70		Rabbit, 15 mg/kg	50% reduction in vascular flow in isolated ear.		51
71		Rabbit, 20 mg/kg	Reduced coronary flow of isolated heart 50%. Complete constriction of medial artery of ear.		
72		Frog, 0.5-5.0 µg	Increased action of acetylcholine on heart. Increased capillary permeability.	Displaced platelets and serum proteins from capillary endothelium.	52,53
73		Frog, 20 µg	Strengthened isolated hypodynamic heart. Increased capillary permeability.		
74		Frog, 50 µg	Increased capillary permeability. Stopped heart.		
75	Toluidine blue, azure A	Dog, rabbit, 1-10 mg/kg	Slight increase in blood pressure. Bradycardia. Increase in T wave and high take off of P. No effect on heart response to acetylcholine or epinephrine. Vasoconstriction of blood vessels in hind leg of dog.	Higher dose required for cardiac effects after atropine. Increased respiratory rate and depth of breathing.	54
76		Rabbit, isolated heart	No effect on transmission, cytotoxic effect.		55
77		Frog, isolated heart	Cholinergic blockade.		55
78	Dicumarol	Man	No effect on normal or abnormal ECG.		56
79			No effect on ECG with standard exercise tests.		24
80		Man, arteriosclerotic	Slight reduction in extremity blood flow (plethysmograph).		57
81		Dog	Increased coronary flow.		45
82		Rabbit, 5-20 mg/kg	Momentary slight rise in blood pressure. 0.25% caused inhibition of isolated heart. Perfusion of peripheral vein, contraction, large doses caused dilatation.	No effect on respiration.	58,59
83		Rabbit, 10 mg/kg	Pronounced engorgement of great veins.		60
84	Dicumarol, plus ergotamine	Rat	No effect on gangrene.		43
85	Dicumarol (also 4 hydroxycoumarin and indanediones)	Cat, rabbit, 10-50 mg/kg	Usually decreased, sometimes increased, blood pressure.	Rapid rise in O_2 consumption, respiratory rate and amplitude. Effects on O_2 consumption; increased by vitamin K_3, not by K_1.	61
86	2-Isovaleryl-1,3-indanedione	Cat, 5-60 mg/kg	Decline in blood pressure. Rapid vasodilation (direct).	Increase in depth of breathing.	62

Contributor. Jaques, Louis B.

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109. DRUGS PRIMARILY USED FOR DISORDERS OF THE CIRCULATORY SYSTEM

Drugs listed are characterized by prominent hemodynamic actions; grouping is based on a common action or common source Official generic names are from United States Pharmacopeia XV, National Formulary X, or from New and Nonofficial Remedies, 1955 Clinical Use AA = antiarrhythmic drugs, for control of cardiac arrhythmia, prophylactic and curative, AH = antihypertensive drugs, for acute and chronic relief of essential and other forms of hypertension, CT = cardiotonic drugs, for management of congestive heart failure, HT = hypertensive drugs, for pressor action in correction of hypotensive states, and for local vasoconstrictor action in nasal congestion, VD = vasodilators, for improving blood flow in diseased limb and coronary vascular beds, and for relief of systemic hypertension. Route IH = inhalation, IM = intramuscular; IV = intravenous, PO = oral, SC = subcutaneous, SL = sublingual; TOP = topical application

	Drug (Synonym)	Clinical Use	Route	Average Adult Dose	Effect: Desirable	Effect: Undesirable	Hemodynamic Effects Found on Following Pages
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Veratrum Alkaloids						
1	Alkavervir (Veriloid)	AH	PO IM, IV	9-15 mg daily 0 5-1 0 mg	Hypotension without tachycardia.	Severe bradycardia, nausea, vomiting, salivation, and sweating.	258
2	Protoveratrines A and B[1] (Veralba, Provell maleate)	AH	PO	1-2.5 mg daily			261,268
3	Veratrone	AH	PO	0.25-0.5 mg daily			253,261,264,265, 268
4	Vergitryl[2]	AH	PO	3-15 units daily			
5	Vertavis[3]	AH	PO	3-15 units daily			
	Rauwolfia Alkaloids						
6	Alseroxylon (Rauwiloid, Rautensin, Rau-Tab, Rauwistan)	AH	PO	2-4 mg daily	Hypotension without tachycardia.	Mental depression, nasal congestion, nausea, bradycardia, weakness and fatigue.	
7	Raudixin, Rauwal	AH	PO	50-500 mg daily			
8	Rescinnamine	AH	PO	2-4 mg daily			
9	Reserpine (Serpasil, Serpiloid, Reserpoid, Raused serpate)	AH	PO	0.1-2 mg daily			253,258,261,271
	Miscellaneous Antihypertensives						
10	Hydralazine (Apresoline)	AH	PO	100-400 mg daily	Hypotension	Palpitation, headache, lupus-like syndrome.	253,257,261,265, 267
11	Potassium or sodium thiocyanate	AH	PO	0.05-1.4 g daily		Drowsiness, vomiting	253
	Ganglion Blocking Drugs						
12	Azamethonium dibromide (Pendiomide)	VD	IV	50-100 mg	Increased blood flow in limbs, lowering of arterial pressure if hypertension present.	Severe hypotension (unless intentional for hypertensive surgery), generalized ganglion blockade manifested as blurring of vision, dryness of mouth, tachycardia, constipation.	252,258,261,266
13	Chlorisondamine dimethochloride (Ecolid)	VD	PO	50-100 mg daily			261,266
14	Hexamethonium bromide or chloride (Bistrium, Methium, Esomid, Hexameton, Hiohex)	VD	PO IV, SC	200-400 mg 5-100 mg			252,257,258,261, 263,266
15	Mecamylamine HCl (Inversine)	VD	PO	20 mg daily			261
16	Pentolinium tartrate (Ansolysen, Pentapyrrolidinium)	VD	PO	20-100 mg			
17	Pentamethonium chloride	VD	IV	100-150 mg			253,267
18	Tetraethylammonium bromide or chloride (Etamon)	VD	IV, IM	200-500 mg			253,263,267,271
19	Trimethaphan camphorsulfate (Arfonad)	VD	IV	1 mg/min			253,261

/1/ Base, not the salt. /2/ Standardized for hypotensive potency by effect on carotid sinus reflex in vagotomized dogs /3/ Standardized by its cardiac arrest in a crustacean, Daphnia magna.

Representative drugs are listed in tables 109 and 110 on the pages indicated in columns D and F.

	Site of Action		Stimulant	Page	Depressant	Page
	General	Specific				
	(A)	(B)	(C)	(D)	(E)	(F)
			Nervous Mechanisms Controlling Circulation			
1	Central nervous system (direct action)	Vasoconstrictor center	Analeptics.[1]	251	General anesthetics.[1]	250
2		Cardio-accelerator center				
3		Cardio-inhibitory center[2]	General anesthetics [1]	250	Analeptics [1]	251
4		Other areas that modify vasomotor activity, so far unidentified	None recognized		Rauwolfia alkaloids.	247
					Hydralazine.	247
					Morphine.	250
5	Sensory receptors in heart, lungs, blood vessels	Stretch receptors in carotid sinuses and aortic arch[3]	Local application of sympathomimetic amines.	248, 249	Local anesthetics.	250
			Veratrum alkaloids (esters of tertiary amines).	247	Receptors indirectly inactivated by hypotensive drugs.	248
			Activated indirectly by hypertensive drugs.	248, 249		
6		Chemoreceptors in carotid and aortic bodies[4]	Ganglion stimulants.	252	Local application of ganglion blocking drugs depresses action of ganglion stimulants. O_2 inhalation depresses action of cyanide.	247
			Inhibitors of oxidation, such as cyanide and sulfide.	252		
			Papaverine	248		
			Nikethamide.	251		
			Aminophylline.	248		
7		Stretch receptors in heart, lung parenchyma, and blood vessels[5]	Veratrum alkaloids (esters of tertiary amines).	247	Local anesthetics.	250
8		Receptors of various types in respiratory passages and joints[6]	Veratrum alkaloids (esters of tertiary amines).	247	High concentration of volatile anesthetics.	250
			Low concentration of volatile anesthetics.	250		
9	Autonomic nervous system	Ganglia, both sympathetic[7] and parasympathetic[8]	Ganglion stimulants.	252	Ganglion blocking drugs.	247
					High concentration of nicotine.	252
10		Sympathetic[7]	Sympathomimetics.	248-9	Adrenergic blocking drugs.	248
11		Parasympathetic[8]	Parasympathomimetics.	248	Parasympathetic blocking drugs.	251
			Muscular Components of Circulatory System			
12	Blood vessels	With specific antagonist	Methacholine.	248	Atropine.	251
			Histamine.	252	Antihistamines.	251
13		Without specific antagonist	Musculotropic vasoconstrictors.	251, 252	Musculotropic vasodilators.	248
14	Heart	Contractility of heart muscle	Cardiac glycosides.	249, 250	Quinidine.	250
					General anesthetics.[1]	250
15		Ectopic automaticity of heart	Profibrillatory drugs Chloroform.	250	Antifibrillatory drugs	250
			Cyclopropane.	250	Quinidine.	250

/1/ None selective. /2/ Reciprocal innervation with cardio-accelerator center. /3/ Type 1 receptors, producing perfect inhibition of vasoconstrictor, cardio-accelerator and respiratory centers /4/ Type 3 receptors, producing pure stimulation of vasoconstrictor, cardio-accelerator and respiratory centers. /5/ Type 2 receptors, producing imperfect inhibition of vasoconstrictor, cardio-accelerator and respiratory centers. /6/ Type 4 receptors, producing imperfect stimulation of vasoconstrictor, cardio-accelerator and respiratory centers. /7/ Sympathetic stimulation causes cardiac acceleration and constriction of most blood vessels. /8/ Parasympathetic stimulation causes cardiac slowing and dilatation of some blood vessels.

Contributors (a) Aviado, Domingo M., Jr., and Carl F. Schmidt, (b) Krayer, Otto

Reference: Aviado, D. M., Jr., and C. F. Schmidt. 1955. Physiol. Rev. 35:247.

109. DRUGS PRIMARILY USED FOR DISORDERS OF THE CIRCULATORY SYSTEM (Continued)

	Drug (Synonym)	Clinical Use	Route	Average Adult Dose	Effect: Desirable	Effect: Undesirable	Hemodynamic Effects Found on Following Pages:
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Sympathomimetic Amines for Systemic Pressor Action (concluded)						
49	Epinephrine, epinephrine bitartrate (Adrenalin, Suprarenin)	HT	SC IV	0 5 mg 5 μg/min	Rise in systemic arterial pressure.	Some amines induce cardiac arrhythmias and cerebral excitation.	254,257,259,262, 264,267,270
50	Hydroxyamphetamine hydrobromide (Paredrine)	HT	IM TOP	10 mg 0.25-1%			254,264
51	Levarterenol bitartrate (Levophed, Noradrenalin)	HT	IV	5 μg/min			254,257,259,262, 264,267,270
52	Mephentermine sulfate (Wyamine)	HT	IM, IV TOP	20 mg 0.5%			254,264,270
53	Methamphetamine HCl (Methedrine, Desoxyephedrine, Desoxin, Dexoval, Doxyfed, Efroxine, Norodin)	HT	PO SC, IM, IV TOP	5 mg 10-30 mg 0.5-1%			270
54	Methoxamine HCl (Vasoxyl)	HT	IM	5 mg			254,257,264,271
55	Oenethyl HCl	HT	IV IM	10-25 mg 75-100 mg			
56	Phenylephrine HCl (Neosynephrine, Isophrin)	HT	SC, IM IV TOP	5 mg 0.5 mg 0.25%			254,264,271
57	Synephrine (Sympatol, Synthenate)	HT	SC, IM	100 mg			
	Sympathomimetic Amines for Topical Application Only						
58	Amphetamine sulfate (Benzedrine, Actedron)	HT	IH		For local nasal decongestion only; these amines are too toxic for parenteral use, with the exception of amphetamine sulfate and dextroamphetamine sulfate.		259,270
59	Dextroamphetamine sulfate (Dexedrine)	HT	TOP	1%			
60	Metaraminol bitartrate (Aramine)	HT	TOP	0.25%			254,259,262,264
61	Methylhexaneamine (Forthane)	HT	IH				
62	Naphazoline HCl (Privine)	HT	TOP	0.1%			
63	Nordefrin HCl (Cobefrin)	HT	TOP	0 01%			
64	Phenylpropanolamine HCl (Propadrine)	HT	TOP	1%			270
65	Phenylpropylmethylamine (Vonedrine)	HT	IH, TOP	2.8%			270
66	Propylhexedrine (Benzedrex)	HT	IH				
67	Tuaminoheptane sulfate (Tuamine)	HT	IH, TOP	1%			270
	Cardiac Glycosides[5]						
68	Deslanoside (Cedilanid D)	CT	IV: I	1.6 mg	Improved ventricular function of heart in failure with and without atrial fibrillation; A-V block.	Anorexia, vomiting, headache, yellow vision, muscular weakness, ventricular arrhythmia, excessive A-V block.	
69	Digifolin	CT	PO: I M	10 units 1 unit			
70	Diglanid	CT	PO: I M IV, I	3-6 mg 0.3-0 6 mg 0.8-1.6 mg			
71	Digitalis, powdered	CT	PO: I M	1-2 g 0.1-0 2 g			254,259,264,270
72	Digitalis, tincture[6]	CT	PO: M	1-2 ml			
73	Digitoxin	CT	PO: I	1.0 mg			
74	Digoxin	CT	PO: I M IV, I	1.5 mg 0 5 mg 1.0 mg			254,262,264
75	Gitalin (Gitaligin)	CT	PO: I M	4-8 mg 0.25-1.0 mg			
76	Lanatoside C (Cedilanid)	CT	PO: I M	8 mg 1 mg			254,264

/5/ I = initial dose, M = daily maintenance doses. /6/ 1 ml tincture = 0.1 g powdered digitalis

	Drug (Synonym)	Clinical Use	Route	Average Adult Dose	Effect: Desirable	Effect: Undesirable	Hemodynamic Effects Found on Following Pages:
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Adrenergic Blocking Drugs						
20	Azapetine phosphate (Ilidar)	VD	PO	75-300 mg daily	Increased blood flow to limbs, hypotensive action useful in diagnosis of pheochromocytoma.	Drowsiness, nausea, vomiting, tachycardia, nasal congestion.	261,267
			IV	150 mg			
21	Dibenamine HCl	VD	IV	0.5 mg/kg			253,263,269
22	Dihydroergocornine methanesulfonate	VD	IV, IM	0.25-1 mg			258,267
23	Dihydroergotamine methanesulfonate	VD	IV, IM	1-2 mg			253,263,269
24	Hydergine[4]	VD	SL, IV, IM	0.3-1.0 mg			253,261,263,267
25	Phenoxybenzamine HCl (Dibenzyline)	VD	IV	50-300 mg			258,261,267
			PO	10-60 mg daily			
26	Phentolamine HCl, or methanesulfonate (Regitine)	VD	PO	200-400 mg daily			258,267,269
			IV, IM	5 mg			
27	Piperoxan HCl (Benodaine)	VD	IV	0.25 mg/kg			
28	Roniacol tartrate	VD	PO	30-50 mg daily			267
29	Tolazoline HCl (Priscoline)	VD	PO	200 mg daily			253,258,263,267, 269
			IV, IM, SC	15-25 mg			
	Cholinergic Vasodilators						
						Peripheral vasodilatation accompanied by parasympatho-	257,265,270
							253
	(Mecholyl)						254,267,271
33	Amyl nitrite	VD					
34	Erythrityl tetranitrate	VD		daily		emia, development of tolerance.	
35	Glyceryl trinitrate (Nitroglycerin)	VD	SL	0.4 mg			254,257,258,269
36	Inositol hexanitrate	VD	PO	30-90 mg daily			
37	Mannitol hexanitrate	VD	PO	50-150 mg daily			
38	Pentaerythritol tetranitrate (Peritrate)	VD	PO	30-60 mg daily			
39	Sodium nitrite	VD	PO	100-200 mg daily			254,264
40	Triethanolamine trinitrate biphosphate (Metamine)	VD	PO	2-6 mg daily			
41	Aminophylline (Theophylline ethylenediamine)	VD	PO	0.5-1.0 g		Variable effects on coronary and limb blood flow, inconstant clinical results.	253,257,258,261, 264,270
			IM, IV	0.25-0.5 g			
42	Dioxyline phosphate (Paveril)	VD	PO	0.6 g			
43	Ethyl alcohol	VD	PO	Variable			254,257,259,261, 267
44	Khellin (Eskel)	VD	PO	30-160 mg			254,257,265
	[illegible]		IM	[illegible] mg	arterial pressure.	induce cardiac arrhythmias and cerebral excitation.	
			TOP	0.5 %			
48	Ephedrine sulfate	HT	PO, SC, IM	15-50 mg			254,270

/4/ Equal parts of dihydroergocornine, dihydroergocristine, and dihydroergokryptine methanesulfonates.

109. DRUGS PRIMARILY USED FOR DISORDERS OF THE *CIRCULATORY* SYSTEM (Continued)

No.	Drug (Synonym)	Clinical Use	Route	Average Adult Dose	Effect: Desirable	Effect: Undesirable	Hemodynamic Effects Found on Following Pages*
	(A)			(D)	(E)	(F)	(G)
						...ded) ... iiac ... as	254,257,259,262, 264,267,270
49	Epinephrine, epineph bitartrate (Adrenalin, Suprarenin)				...ult.	and cerebral excitation.	254,264
50	Hydroxyamphetamine hydrobromide (Paredrine)	HT	IM	10 mg			254,257,259,262, 264,267,270
			TOP	0.25-1%			
51	Levarterenol bitartrate (Levophed, Noradrenalin)	HT	IV	5 μg/min			254,264,270
52	Mephentermine sulfate (Wyamine)	HT	IM, IV	20 mg			270
			TOP	0.5%			
53	Methamphetamine HCl (Methedrine, Desoxyephedrine, Desoxin, Dexoval, Doxyfed, Efroxine, Norodin)	HT	PO	5 mg			254,257,264,271
			SC, IM, IV	10-30 mg			
			TOP	0.5-1%			
54	Methoxamine HCl (Vasoxyl)	HT	IM	5 mg			
55	Oenethyl HCl	HT	IV	10-25 mg			254,264,271
			IM	75-100 mg			
56	Phenylephrine HCl (Neosynephrine, Isophrin)	HT	SC, IM	5 mg			
			IV	0.5 mg			
			TOP	0.25%			
57	Synephrine (Sympatol, Synthenate)	HT	SC, IM	100 mg			
	Sympathomimetic Amines for Topical Application Only						
58	Amphetamine sulfate (Benzedrine, Actedron)	HT	IH		For local nasal decongestion only, these amines are too toxic for parenteral use, with the exception of amphetamine sulfate and dextroamphetamine sulfate.		259,270
59	Dextroamphetamine sulfate (Dexedrine)	HT	TOP	1%			
60	Metaraminol bitartrate (Aramine)	HT	TOP	0.25%			254,259,262,264
61	Methylhexaneamine (Forthane)	HT	IH				
62	Naphazoline HCl (Privine)	HT	TOP	0.1%			
63	Nordefrin HCl (Cobefrin)	HT	TOP	0.01%			
64	Phenylpropanolamine HCl (Propadrine)	HT	TOP	1%			270
65	Phenylpropylmethylamine (Vonedrine)	HT	IH, TOP	2.8%			270
66	Propylhexedrine (Benzedrex)	HT	IH				
67	Tuaminoheptane sulfate (Tuamine)	HT	IH, TOP	1%			270
	Cardiac Glycosides[5]						
68	Deslanoside (Cedilanid D)	CT	IV, I	1.6 mg	Improved ventricular function of heart in failure with and without atrial fibrillation; A-V block.	Anorexia, vomiting, headache, yellow vision, muscular weakness, ventricular arrhythmia, excessive A-V block.	
69	Digifolin	CT	PO I	10 units			
			M	1 unit			
70	Digilanid	CT	PO I	3-6 mg			
			M	0.3-0.6 mg			
			IV, I	0.8-1.6 mg			
71	Digitalis, powdered	CT	PO I	1-2 g			254,259,264,270
			M	0.1-0.2 g			
72	Digitalis, tincture[6]	CT	PO M	1-2 ml			
73	Digitoxin	CT	PO I	1.0 mg			
74	Digoxin	CT	PO I	1.5 mg			254,262,264
			M	0.5 mg			
			IV; I	1.0 mg			
75	Gitalin (Gitaligin)	CT	PO I	4-8 mg			
			M	0.25-1.0 mg			
76	Lanatoside C (Cedilanid)	CT	PO I	8 mg			254,264
			M	1 mg			

/5/ I = initial dose, M = daily maintenance doses. /6/ 1 ml tincture = 0.1 g powdered digitalis.

109. DRUGS PRIMARILY USED FOR DISORDERS OF THE CIRCULATORY SYSTEM (Concluded)

	Drug (Synonym)	Clinical Use	Route	Average Adult Dose	Effect: Desirable	Effect: Undesirable	Hemodynamic Effects Found on Following Pages
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Cardiac Glyc[illegible]						
[illegible]	[illegible]			[illegible]	heart in failure with and without *atrial fibrillation*; A-V block.	yellow vision, muscular weakness, ventricular arrhythmia, excessive A-V block.	257
	Cinchona Alkaloids						
82	Quinidine gluconate	AA	IM	0.4-0.8 g	Antifibrillatory action.	Cinchonism, vascular collapse following IV injection.	
83	Quinidine HCl	AA	IM, IV	0.45-0.65 g			
84	Quinidine sulfate	AA	PO	0.2 g			255,269
	Synthetic Antiarrhythmic Drugs						
85	Ambonestyl HCl	AA	IV	0.5 g		Depression of cardiac muscle contractility and hypotension.	269
86	Procaine amide HCl (Pronestyl)	AA	PO	6.0 g			255,264,269
			IV	1 g			

/5/ I = initial dose, M = daily maintenance doses.

Contributors: (a) Aviado, Domingo M., Jr., and Carl F. Schmidt, (b) Krayer, Otto, (c) Freis, Edward D.

110. DRUGS PRIMARILY USED FOR DISORDERS NOT LIMITED TO THE CIRCULATORY SYSTEM

Drugs listed are primarily used for disorders of systems other than the circulatory; grouping is based on a common action. Official generic names are from United States Pharmacopeia XV, National Formulary X, or from New and Nonofficial Remedies, 1955.

	Drug	Use in Clinical Disorder of Circulatory System	Cardiovascular Action	Hemodynamic Effects Found on Following Pages
	(A)	(B)	(C)	(D)
	Hypnotics and Sedatives			
1	Amobarbital sodium	Sedative in hypertension and heart disease.	Large doses depressant to heart muscle contraction.	255
2	Pentobarbital sodium			267
3	Phenobarbital sodium			271
	Analgesics			
4	Meperidine HCl	Sedative for acute myocardial infarction or acute congestive failure.	Large doses produce vasomotor depression and bradycardia.	269
5	Morphine sulfate or tartrate			262
6	Sodium salicylate	Antipyretic for rheumatic carditis.	Claimed to have direct effect on cardiac lesion.	255
	General Anesthetics			
7	Chloroform	No direct use, cardiac patients may be subjected to general anesthetics if necessary.	Depressant to heart muscle contraction, in general, all general anesthetics act as dilators of blood vessels; chloroform and cyclopropane can cause dangerous cardiac arrhythmias.	271
8	Cyclopropane			255,271
9	Ether			255,271
10	Ethyl chloride			
11	Nitrous oxide			271
12	Thiopental sodium			255,259,271
13	Trichloroethylene			271
14	Vinyl ether			271
	Local or Spinal Anesthetic			
15	Procaine HCl	Applied locally to exposed heart *during cardiac surgery to* prevent arrhythmia.	Spinal anesthesia may reduce arterial *blood pressure by sympathetic* blockade and decreased thoracic movement.	255,257,259,262, 264,268,269
	Anticonvulsants			
16	Diphenylhydantoin sodium	None	Antiarrhythmic activity.	269
17	Trimethadione			

110. DRUGS PRIMARILY USED FOR DISORDERS NOT LIMITED TO THE CIRCULATORY SYSTEM (Continued)

	Drug	Use in Clinical Disorder of Circulatory System	Cardiovascular Action	Hemodynamic Effects Found on Following Pages
	(A)	(B)	(C)	(D)
		Analeptics		
18	Caffeine and sodium benzoate	Stimulant to vasomotor and respiratory centers.	Direct contraction of heart muscle and dilatation of blood vessels.	258,270
19	Nikethamide		Direct effects on heart and coronaries uncertain.	257
		Tranquilizing Drug		
20	Chlorpromazine	Prevention of nausea in uremia, eclampsia and veratrum therapy, and relief of mental aberrations	Essentially secondary to actions on nervous system.	259,271
		Sympathomimetic Bronchodilators		
21	Isoproterenol HCl	Relief of bronchial asthma.	Hypotension.	254,264,267,270
22	Methoxyphenamine HCl			
		Parasympathetic Blocking Drugs		
23	Atropine sulfate	Diagnosis and treatment of cardiac arrhythmia due to increased vagal tone; antidote for poisoning by anticholinesterase agents	Cardio-accelerator.	267,270
24	Methantheline bromide			
25	Scopolamine hydrobromide			
		Neuromuscular Blocking Drugs		
26	Succinylcholine chloride	None.	Curare preparations cause hypotension by histamine liberation, ganglion blockade, and decreased muscle tonus	
27	Tubocurarine chloride			267
		Antihistamines		
28	Diphenhydramine HCl	None.	Antifibrillatory action demonstrated in animals.	269
29	Pyrilamine maleate			
30	Tripelennamine HCl			
		Diuretics		
31	Acetazolamide (Diamox)	Mobilization of water and sodium ion in congestive heart failure	Decreased blood volume aids in treating congestive heart failure, large doses depressant to heart muscle.	
32	Meralluride sodium			
33	Mercurophylline sodium			
34	Mersalyl sodium			255
		Anticoagulants		
35	Bishydroxycoumarin	Prophylaxis against thromboembolic diseases	Prevention of thrombosis and emboli in coronary and other vascular beds.	
36	Heparin			259
		Antibiotics		
37	Benzathine penicillin G	Control of subacute bacterial endocarditis	Secondary to arrest of infectious process	
38	Procaine penicillin G			260
		Antimalarials		
39	Chloroquine diphosphate	Antifibrillatory agent	Decreased automaticity (ectopic) and contractility of heart muscle	269
40	Quinacrine HCl			269
		Endocrine Preparations		
41	Corticotropin	None	None	
42	Cortisone acetate			259
43	Desoxycorticosterone acetate			255
44	Insulin			259
45	Pitressin			259
46	Posterior pituitary extract		Vasoconstrictor.	255,265
47	Thiouracil	Treatment of hyperthyroid heart disease	None directly	260
		Vitamins		
48	Cyanocobalamin (B12)	None	None	
49	Nicotinic acid	Treatment of peripheral vascular disease	Vasodilator[1]	259
50	Thiamine HCl	Treatment of cardiac beriberi	None, unless deficiency symptoms exist.	254,259,267

/1/ Questionable

	Drug	Use in Clinical Disorder of Circulatory System	Cardiovascular Action	Hemodynamic Effects Found on Following Pages
	(A)	(B)	(C)	(D)
	Plasma Expanders			
51	Dextran, 6% solution	Plasma expander in shock.	Increased cardiac output.	265
52	Gelatin, 6% solution			
53	Sodium chloride, 0.9% solution			260,262,265
	Anions and Cations			
54	Ammonium chloride	Limited clinical trial as antiarrhythmic drug or as stimulant to arrested ventricles.	Alterations in automaticity of heart.	259
55	Barium chloride			270
56	Calcium chloride			271
57	Magnesium sulfate			262,271
58	Potassium chloride			271
59	Sodium bicarbonate			260
60	Sodium lactate			270
	Miscellaneous Drugs for Animal Experimental Use			
61	Aconitine	None because of toxicity.	Proarrhythmic.	270
62	Chloralose		General anesthetic.	
63	β-Dihydrosolasodine		Antiaccelerator.	270
64	DMPP (1,1-Dimethyl-4-phenylpiperazinium iodide)		Ganglion stimulant.	
65	α-Fagarine		Antiarrhythmic.	269
66	Histamine phosphate or diphosphate		Vasodilator.	257,258,262,265, 267
67	Lobeline		Ganglion stimulant.	
68	Nicotine			
69	Serotonin (5-Hydroxytryptamine)		Vasoconstrictor.	255,265
70	Sodium cyanide		Chemoreceptor stimulant.	
71	Sodium sulfide			
72	Urethane		General anesthetic.	271
73	Veratramine		Antiaccelerator.	271
74	Veratridine		Visceral receptor stimulant.	

Contributors: (a) Aviado, Domingo M., Jr., and Carl F. Schmidt, (b) Krayer, Otto

111. HEMODYNAMIC EFFECTS OF DRUGS: MAMMALS

Part I: MEAN ARTERIAL PRESSURE, CARDIAC OUTPUT, AND TOTAL VASCULAR RESISTANCE· MAN, DOG

Values are averages for reported number of cases and represent per cent change from control. Route IH = inhalation, IM = intramuscular, IS = intraspinal, IV = intravenous; PO = oral, SC = subcutaneous, SL = sublingual. (+) = increase, (-) = decrease, (0) = no significant change.

	Drug	Route	Dose	Subjects: Animal	Subjects: No.	Subjects: Condition	Mean Arterial (Systemic) Pressure[1] (% Change)	Cardiac Output[2] (% Change)	Total Vascular (Systemic) Resistance[3] (% Change)	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Ganglion Blocking Drugs									
1	Azamethonium dibromide	IV	0.6-1.4 mg/kg	Man	10	Peripheral vascular disease	-8	+23 BCG		1
2	Hexamethonium bromide or chloride	IV	0.2-1 mg/kg	Man	10	Normotension	-20	+	-17	2
3				Man	5	Hypertension	-25	-46		3
4				Man	6	Hypertension, compensated	-24	-22	0	4
5				Man	4	Hypertension, decompensated	-31	+38	-47	4

/1/ Measured by mercury manometer or electrometer. /2/ Measured by Fick principle, unless otherwise indicated (BCG = ballistocardiograph, DYE = dye-dilution technique). /3/ Ratio of pressure to flow, or absolute values.

111. HEMODYNAMIC EFFECTS OF DRUGS. MAMMALS (Continued)

Part I. MEAN ARTERIAL PRESSURE, CARDIAC OUTPUT, AND TOTAL VASCULAR RESISTANCE: MAN, DOG (Continued)

	Drug	Route	Dose	Subjects: Animal	Subjects: No.	Subjects: Condition	Mean Arterial (Systemic) Pressure[1]	Cardiac Output[2]	Total Vascular (Systemic) Resistance[3]	Reference
							% Change			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Ganglion Blocking Drugs (concluded)									
	Hexamethonium bromide or chloride (concluded)	IV	0.2-1 mg/kg	Man	8	Pulmonary hypertension	-27	-16	-12	5
				Dog		Anesthetized	-35	-30		6
8	Pentamethonium bromide	IV	0.3-0.7 mg/kg	Man	14	Peripheral vascular disease	-11	+29 BCG		1
9	Tetraethylammonium bromide or chloride	IV	2-6 mg/kg	Man	14	Normotension	-10	0	-	7,8
10				Man	4	Hypertension	-	-	-	9
11				Man	5	Mitral stenosis	-5	+12	-27	10,11
12				Man	5	Left heart failure	-21	0	-28	10
13				Man	10	Cardiopulmonary disease	-	-32	-	7
14				Man	11	Peripheral vascular disease	-5	+35		12
15	Trimethaphan camphorsulfate	IV	0.03-0.2 mg/kg	Man	2	Normotension, non-pregnant	-5	0 BCG	-8	13
16				Man	5	Normotension, pregnant	-38	-19 BCG	-22	13
17				Man	3	Hypertension, pregnant	-33	-18 BCG	-19	13
	Adrenergic Blocking Drugs									
18	Dibenamine HCl	IV	0.5-3.0 mg/kg	Man	9	Normotension	-8	0		8
19				Man	4	Mitral stenosis	-6	+7		10
20				Man	3	Congestive heart failure		+28		14
21				Man	4	Left heart failure	-9	-6	-4	10
22	Dihydroergotamine methanesulfonate	IV	1 mg	Man	46	Normotension	+3	0	+45	8,10, 15
23	Hydergine	IV	0.5 mg	Man	9	Normotension	-4	0	-5	15
24	Tolazoline HCl	IV	0.4-0.6 mg/kg	Man	16	Peripheral vascular disease	+8	+28 BCG		16
	Antihypertensive Drugs									
25	Hydralazine	IV	0.2-5 mg/kg	Man	4	Normotension	-20	+110	-61	17
26				Man	17	Hypertension	-17	+33	-31	18
27				Man	11	Hypertension	-28	+27	-32	19
28										
29										
30						pregnancy				
31	Reserpine	PO	1 mg daily for 6-35 wks	Man	54	Hypertension	-	+ BCG		23
32		IV		Dog	5	Anesthetized	0	0		24
33	Sodium thiocyanate	IV	5-100 mg/kg	Dog	15	Anesthetized	0	-18	+	25
34	Veratrone	IM	0.4-1.0 ml	Man	2	Hypertension, compensated	-11	0	-6	26
35				Man	3	Hypertension, decompensated	-14	0	-21	26
	Miscellaneous Vasodilators									
36	Aminophylline	IV,IM	0.5 g	Man	7	Hypertension, compensated	0	+6	-4	27
37				Man	4	Hypertension, decompensated	+8	+33	-17	27
38				Man	7	Normotension	+7	+25 BCG	-19	28
39	Carbachol	SC	0.5 mg	Man	6	Peripheral vascular disease	-7	+12 BCG	-17	28

/1/ Measured by mercury manometer or electrometer. /2/ Measured by Fick principle, unless otherwise indicated (BCG = ballistocardiograph, DYE = dye-dilution technique). /3/ Ratio of pressure to flow, or absolute values.

Part I: MEAN ARTERIAL PRESSURE, CARDIAC OUTPUT, AND TOTAL VASCULAR RESISTANCE: MAN, DOG (Continued)

	Drug	Route	Dose	Subjects: Animal	Subjects: No.	Subjects: Condition	Mean Arterial (Systemic) Pressure[1]	Cardiac Output[2]	Total Vascular (Systemic) Resistance[3]	Reference
							% Change			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Miscellaneous Vasodilators (concluded)									
40	Ethyl alcohol	PO	60-150 ml, 40%	Man	5	Peripheral vascular disease	0	-5 BCG		12
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	...tension	[illegible]	[illegible]	[illegible]	[illegible]
43				Man	5	Chronic pulmonary disease		0		31
44	Methacholine chloride	SC	3.7-5 mg	Man	3	Peripheral vascular disease	+7	+29 BCG		12
45	Nicotinic acid	PO	50-100 mg	Man	8	Peripheral vascular disease	0	-4 BCG		12
46	Sodium nitrite	IV	40-60 mg	Man	14	Various cardio-vascular diseases	-3	+21		8
47				Man	4	Mitral stenosis	-5	+11	-15	10
48				Man	5	Left heart failure	-5	+10	-13	10
49	Ephedrine sulfate	SC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50	Epinephrine	SC,IM[4]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54	Hydroxyamphetamine	IM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]									
	...sulfate									
62	Metaraminal bitartrate	IV	0.65 mg	Man	7	Normotension	+50	0	+55	40
63	Methoxamine HCl	IV	10 µg/kg/min	Dog	4	Anesthetized	+	-30	+	41
64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]					...failure				
71				Man	5	Left ventricular failure	0	+25	-28	45
72				Man	3	Cor pulmonale, not in failure	+18	0	+7	46
73				Man	5	Cor pulmonale, in failure	+10	+15	+2	46
74				Man	12	Enlarged heart, not in failure	+6	+9		47
75				Man	2	Pulmonary hyper-tension	+11	+7	+5	46
76	Lanatoside C	IV	1.5 mg	Man	6	Mitral stenosis	+	+		48
77				Man	9	Chronic pulmonary disease		+		49

...ple, unless otherwise indicated

...flow, or absolute values.

Part I. MEAN ARTERIAL PRESSURE, CARDIAC OUTPUT, AND TOTAL VASCULAR RESISTANCE: MAN, DOG (Continued)

	Drug	Route	Dose	Subjects			Mean Arterial (Systemic) Pressure[1]	Cardiac Output[2]	Total Vascular (Systemic) Resistance[3]	Reference
				Animal	No.	Condition	% Change			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	General Anesthetics and Sedatives									
78	Amobarbital sodium	PO	0.4 g	Man	5	Normotension	-8	-26 BCG	+44	50
79				Man	5	Hypertension	-13	-26	+26	50
80	Cyclopropane	IH		Dog	21	Blood level, 9-29 mg %	0	0 DYE	0	51,52
81	Ether	IH		Dog	20	Blood level, 85-185 mg %	-5	+71 DYE	-44	51,52
82		IH		Dog	9	Blood level, 31-190 mg %		+100		53
83	Thiopental sodium	IV		Man	15	Light surgical anesthesia	-19	-24 DYE	0	54
84				Man	15	Deep surgical anesthesia	-16	-20 DYE	+4	55
85				Man	14	Deep surgical anesthesia	-4	-25 DYE		56
	Miscellaneous Drugs									
86	Cortisone acetate	PO	2-6 g daily for 17-29 da	Man	9	Normal	+	0		57
87	Mersalyl sodium	IV	3 ml	Man	11	Congestive heart failure		+19		58
88	Posterior pituitary extract	SC,IV	20 units	Man	7	Various diseases	-2	-2 BCG	-1	28
89				Dog	10	Anesthetized		-54		59
90	Procaine amide HCl	IV	1 g	Man	10	Heart disease	-17	-11 DYE	+5	60
91	Procaine HCl	IV	0.25-0.5 g	Man	9	Normal	+2	-2 BCG		61
92				Man	9	Peripheral vascular disease	-/+[6]	+6 BCG		61
93		IS	0.25-0.5 g	Man	12	Pregnant, high spinal anesthesia	-	+23 BCG		62
94	Quinidine sulfate	PO	0.8-1.2 g	Man	11	Normal heart	-25	0	-	63
95				Man	8	Heart disease	0	-4 BCG	+4	28
96	Serotonin	IV	0.5 mg	Dog	25	Anesthetized	+	+30 DYE	-3	64
97	Sodium salicylate	IV	100 mg/kg	Dog	7	Anesthetized	+3	+14		65

/1/ Measured by mercury manometer or electrometer. /2/ Measured by Fick principle, unless otherwise indicated (BCG = ballistocardiograph, DYE = dye-dilution technique. /3/ Ratio of pressure to flow, or absolute values. /6/ Decreased systolic but increased diastolic blood pressure

Contributors: Aviado, Domingo M., Jr., and Carl F Schmidt

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Part I: MEAN ARTERIAL PRESSURE, CARDIAC OUTPUT, AND TOTAL VASCULAR RESISTANCE: MAN, DOG (Concluded)

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t II CORONARY BLOOD FLOW, VASCULAR RESISTANCE, AND CARDIAC O_2 UPTAKE: MAN, DOG, RABBIT

ues are averages for reported number of cases and represent *per cent* change from control. Route: CA = injec-
i directly *into coronary* artery; IH = inhalation; IM = intramuscular, IS = intraspinal, IV = intravenous. *Method*
) = nitrous oxide sampling [16]. RTM = rotameter inserted into coronary *artery*; BFM = bubble flowmeter
erted into coronary artery, CSC = collection of coronary sinus outflow by *Morawitz cannula*, PIH = perfused
lated heart. (+) = increased, (-) = *decreased*, (0) = no significant change.

	Drug	Route	Dose	Subjects			Coronary Blood Flow		Coronary Vascular Resistance[1]	Cardiac O_2 Uptake[2]	Reference
				Animal	No	Condition	Method	% Change			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
	Ganglion Blocking Drugs										
	Hexamethonium bromide or chloride	IV	1 mg/kg	Man	2	Hypertension	N_2O	-	-		1
				Dog	16	Anesthetized	N_2O	-15	+2	+2	2
				Dog	7	Renal hyper-tension	N_2O	-14	+3		2
	Cardiac Glycosides										
	Ouabain	IV	0.03 mg/kg	Dog	11	Anesthetized	N_2O	-11	+34	+4	3
			0.04-0.06 mg/kg	Dog	7	Anesthetized	CSC	+190	-70		4
	K-Strophanthin	IV	0.65 mg	Man	7	Normal	N_2O	-1	-3	+5	5
				Man	5	Heart failure	N_2O	+9	-5	+24	5
	Vasodilators										
8									-4	+8	6
9									-		7
0									-		7
1									-		7
2									-46	+1	8
3									-57		8
4									-		7
5									-		7
6				Dog					-		9
7	Histamine phosphate	CA	20 µg	Dog	9	Anesthetized	RTM	+128	-59		10
18	Papaverine HCl	IV	15-20 µg	Dog	6	Anesthetized	BFM	+60	-		7
19		CA	4-40 µg	Dog	2	Anesthetized	BFM	+20	-		7
	Sympathomimetic Amines										
20	Epinephrine	CA	Hypertensive doses	Dog	4	Anesthetized	RTM	+77		+80	9
21			0.2 µg	Dog	9	Anesthetized	BFM	+35	-		11
22	Levarterenol bitartrate	CA	10 µg	Dog	9	Anesthetized	RTM	+36	-30		10
23	Methoxamine HCl	IV	0.1 mg/kg	Dog	6	Anesthetized	CSC	+			12
2											
				heart							
29	Nikethamide	IV	1-1.25 g	Dog	4	Anesthetized	BFM	+45	-	+13	7
30			0.125-0.75 g	Dog	9	Anesthetized	BFM	+3	-		7
31		CA	5 mg	Dog	3	Anesthetized	BFM	+10	-		7
32	Procaine HCl	IS		Man	6	Low spinal anesthesia	N_2O	-52	+7	-53	15

/1/ Calculated from ratio of mean arterial blood pressure to flow. /2/ Calculated by multiplying blood flow and arterial-sinus O_2 (content) difference.

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Part III. CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE: MAN (Continued)

	Drug	Route	Dose	Subjects		Cerebral Blood Flow[1]		Cerebral Vascular Resistance		Cerebral O_2 Uptake		Reference
				No.	Condition	Control[2]	% Change	Control[3]	% Change	Control[2]	% Change	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
	Sympathomimetic Amines											
29	Amphetamine sulfate	IV	10 mg	2	Brain tumor	40	-2	2.5	+4	2.4	+4	18
30	Epinephrine	IV[5]	20-70 µg/min	7	Normal	50	+22	1.8	0	3.4	+23	22
31				15	Normal	66	-4	1.2	0	4.2	-3	23
32	Levarterenol bitartrate	IV[5]	6-28 µg/min	3	Normal	61	-8	1.6	+37	3.7	-5	22
33				13	Normal	61	-21	1.3	-8	4.0	-5	23
34				4	Normal	62	-12	1.6	+53	4.6	-15	24
35	Metaraminol bitartrate	IV infusion		7	Normal	58	-9	1.6	+50	3.4	-6	24
	Nervous System Depressants											
36	Chlorpromazine	IV	200 mg	7	Normal	41	-9	2.9	-24	2.4	+4	25
37	Ethyl alcohol	IV		8	Normal	52	+8	2.1	-14	2.9	-3	25
38			Plus chlorpromazine	6	Normal	49	-6	2.0	-25	2.2	-4	25
39		PO		10	Normal	68	-18	1.6	+12	3.8	-10	26
40			After antabus	10	Normal	54	+18	2.0	-35	3.2	+16	26
41	Insulin (hypoglycemia)			7	Schizophrenia	54	+11	1.6	-13	3.3	-21	27
42				7	Schizophrenia, in coma	54	+16	1.6	-6	3.3	-42	27
43	Procaine HCl	IS		17	Hypertension	52	-12	3.1	-16	3.3	-3	28
44		Stellate block		13	Normotension and hypertension	49	-2	2.5	+8	3.2	-3	29
45				23	Cerebral vascular disease	57	-6	2.2	+4	3.6	-6	30
46	Thiopental sodium	IV		8	Schizophrenia, under semi-narcosis	54	-2			3.3	0	27
47				8	Normal, anesthetized	61	-25			3.6	-39	31
48				11	Normal, anesthetized	54	+11	1.6	-19	3.3	-36	32
	Miscellaneous Drugs											
49	Ammonium chloride	IV	0.8% (0.3 L)	7	Normal	66	-21	1.3	+23	4.2	+5	33
50	Corticotropin	PO	260-400 mg daily for 4 da	4	Various diseases	52	0	2.2	0	2.9	-14	34
51	Cyanocobalamin, plus liver extract			7	*Pernicious anemia*	91	-56	0.9	+177	2.2	+22	35
52	Desoxycorticosterone acetate	IV	50 mg	15	Normal	58	-5	1.5	+6	3.1	-10	36
53	Digitalis preparations, and diuretics			12	Congestive heart failure	52	-4	3.2	-9	3.1	+13	37
54	Heparin	IV	200 mg	11	Senile dementia	34	-3	3.4	0	2.6	+4	38
55	Nicotinic acid	IV	300-800 mg	20	Various diseases	54	+6	2.3	+9	3.4	-3	39

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow. /5/ Or IM, 1 mg

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Part III: CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE. MAN

Values are per cent change from control. Route: IM = intramuscular, IS = intraspinal, IV = intravenous, PO = oral, SL = sublingual. (+) = increased, (-) = decreased, (0) = no significant change. For a comprehensive review, see reference 43.

	Drug	Route	Dose	Subjects		Cerebral Blood Flow[1]		Cerebral Vascular Resistance		Cerebral O_2 Uptake		Reference
				No.	Condition	Control[2]	% Change	Control[3]	% Change	Control[2]	% Change	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
	Ganglion Blocking Drugs											
1	Azamethonium dibromide	IV	1-6 mg/min	5	Normotension	51	-8	2.0	-35	2.8	+7	1
2				9	Normotension	53	+12	1.5	-20	3.2	+10	2
3	Hexamethonium bromide or chloride	IV[4]	1-8 mg/min	9	Normotension	57	-30	1.9	-11	3.2	-12	3
4				8	Normotension	57	-26	1.8	-17	3.2	-9	1
5				7	Young, normotension	46	-33	1.9	-37	2.8	+4	4
6				10	Elderly, normotension	48	-39	1.7	-31	2.7	0	4
7				10	Head up 15°, normotension	53	-11	2.4	-45	3.3	+3	5
8				8	Essential hypertension	48	-39	2.4	-33	2.8	-4	4
9				7	Malignant hypertension	60	-42	3.0	-17	3.5	-11	4
10				13	Hypertension	55	-16	3 5	-28	3.6	-3	6
11				6	Hypertension	50	-4	3.2	-27	3.5	0	7
	Adrenergic Blocking Drugs											
12	Dihydroergocornine methanesulfonate	IM	0.5 mg	5	Normotension	60	-8	1 7	-12	3.8	-8	8
13				12	Hypertension	58	0	2.9	-31	3 5	+3	9
14	Phenoxybenzamine HCl	IV	0.5-0.7 mg/kg	7	Hypertension	48	-12	3.2	-31	3.6	-14	10
15	Phentolamine HCl	IM	1 mg/kg	6	Hypertension	53	0	2.8	-21	3.2	0	11
16	Tolazoline HCl	IV	20-100 mg	24	Normotension	59	-12	1 7	+6	3.6	-3	12
17				6	Mitral stenosis	45	+22	2 0	-25			13
	Other Hypotensive Drugs											
18	Alkavervir	IV	1 µg/kg/min	27	Hypertension	57	-12	3.2	-28	2.9	+17	14
19	Aminophylline	IV	0.5 g	10	Normal	59	-25	1.7	+24	3.8	0	15
20				16	Congestive heart failure	45	-33	2.6	+8	3.2	-18	16
21	Caffeine and sodium benzoate	IV	0.25-0.5 g	7	Hypertension	54	-13	2.7	+22	3.2	+9	17
22				9	Brain tumor	44	-13	2.1	+28	2 6	+8	18
23	Glyceryl trinitrate	SL	0.6 mg	6	Mitral stenosis	40	-8	2.5	+4	3.3	-3	13
24	Histamine	IV	0.7 mg	10	Normal	57	0	1.7	-30	3.2	+6	18
25	Papaverine	IV	0 06-2.0 g	18	Normotension	57	+12	1 7	-17	3.7	0	19
26				4	Brain tumor	37	+8	3 6	-22	2 3	+4	18
27	Parephyllin	IV	0 5 g	7	Hypertension	45	-4	3.1	+3	2.6	+23	20
28	Reserpine	IV	2.5-5.5 mg	5	Hypertension	50	-2	3.5	-17	3.4	-3	21

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow /4/ Or IM, 1 mg/kg

Part III. CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE MAN (Continued)

	Drug	Route	Dose	Subjects		Cerebral Blood Flow[1]		Cerebral Vascular Resistance		Cerebral O_2 Uptake		Reference
				No	Condition	Control[2]	% Change	Control[3]	% Change	Control[2]	% Change	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
	Sympathomimetic Amines											
29	Amphetamine sulfate	IV	10 mg	2	Brain tumor	40	-2	2.5	+4	2 4	+4	18
30	Epinephrine	IV[5]	20-70 µg/min	7	Normal	50	+22	1.8	0	3.4	+23	22
31				15	Normal	66	-4	1.2	0	4 2	-3	23
32	Levarterenol bitartrate	IV[5]	6-28 µg/min	3	Normal	61	-8	1.6	+37	3.7	-5	22
33				13	Normal	61	-21	1.3	-8	4.0	-5	23
34				4	Normal	62	-12	1.6	+53	4.6	-15	24
35	Metaraminol bitartrate	IV infusion		7	Normal	58	-9	1.6	+50	3.4	-6	24
	Nervous System Depressants											
36	Chlorpromazine	IV	200 mg	7	Normal	41	-9	2.9	-24	2.4	+4	25
37	Ethyl alcohol	IV		8	Normal	52	+8	2 1	-14	2.9	-3	25
38			Plus chlorpromazine	6	Normal	49	-6	2.0	-25	2 2	-4	25
39		PO		10	Normal	68	-18	1 6	+12	3 8	-10	26
40			After antabus	10	Normal	54	+18	2.0	-35	3.2	+16	26
41	Insulin (hypoglycemia)			7	Schizophrenia	54	+11	1.6	-13	3.3	-21	27
42				7	Schizophrenia, in coma	54	+16	1.6	-6	3.3	-42	27
43	Procaine HCl	IS		17	Hypertension	52	-12	3.1	-16	3.3	-3	28
44		Stellate block		13	Normotension and hypertension	49	-2	2.5	+8	3.2	-3	29
45				23	Cerebral vascular disease	57	-6	2.2	+4	3.6	-6	30
46	Thiopental sodium	IV		8	Schizophrenia, under seminarcosis	54	-2			3.3	0	27
47				8	Normal, anesthetized	61	-25			3.6	-39	31
48				11	Normal, anesthetized	54	+11	1.6	-19	3.3	-36	32
	Miscellaneous Drugs											
49	Ammonium chloride	IV	0.8% (0.3 L)	7	Normal	66	-21	1 3	+23	4.2	+5	33
50	Corticotropin	PO	260-400 mg daily for 4 da	4	Various diseases	52	0	2 2	0	2.9	-14	34
51	Cyanocobalamin, plus liver extract			7	Pernicious anemia	91	-56	0.9	+177	2.2	+22	35
52	Desoxycorticosterone acetate	IV	50 mg	15	Normal	58	-5	1 5	+6	3.1	-10	36
53	Digitalis preparations, and diuretics			12	Congestive heart failure	52	-4	3.2	-9	3 1	+13	37
54	Heparin	IV	200 mg	11	Senile dementia	34	-3	3.4	0	2.6	+4	38
55	Nicotinic acid	IV	300-800 mg	20	Various diseases	54	+6	2 3	+9	3.4	-3	39

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow /5/ Or IM, 1 mg

[10] Winbury, M.M., and D. M. Green. 1952. Am. J. Physiol. 170:555. [11] Eckenhoff, J. E., J. H. Hafkenschiel, and C. M. Landmesser. 1947. Ibid. 148:582. [12] West, J. W. Unpublished. [13] Rowe, G. G., J. H. Huston, G. M. Maxwell, A. B. Weinstein, H. Tuchman, and C. W. Crumpton. 1955. J. Clin. Invest. 34:696. [14] Leusen, I. R., and H. E. Essex. 1953. Am. J. Physiol. 172:226. [15] Hackel, D. B., S. M. Sancetta, and J Kleinerman. 1956. Circulation, N. Y. 13:92.

Part III: CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE: MAN

Values are per cent change from control. Route: IM = intramuscular, IS = intraspinal, IV = intravenous, PO = oral, SL = sublingual. (+) = increased, (-) = decreased, (0) = no significant change. For a comprehensive review, see *reference 43*.

	Drug	Route	Dose	Subjects		Cerebral Blood Flow[1]		Cerebral Vascular Resistance		Cerebral O_2 Uptake		Reference
				No.	Condition	Control[2]	%	[illegible]	[illegible]	Control[2]	%	
					tension							
6				10	Elderly, normotension	48	-39	1.7	-31	2.7	0	4
7				10	Head up 15°; normotension	53	-11	2.4	-45	3 3	+3	5
8				8	Essential hypertension	48	-39	2.4	-33	2.8	-4	4
9				7	Malignant hypertension	60	-42	3.0	-17	3.5	-11	4
10				13	Hypertension	55	-16	3.5	-28	3.6	-3	6
11				6	Hypertension	50	-4	3.2	-27	3 5	0	7
	Adrenergic Blocking Drugs											
12	Dihydroergocornine methanesulfonate	IM	0.5 mg	5	Normotension	60	-8	1 7	-12	3 8	-8	8
13				12	Hypertension	58	0	2.9	-31	3.5	+3	9
14	Phenoxybenzamine HCl	IV	0.5-0.7 mg/kg	7	Hypertension	48	-12	3 2	-31	3.6	-14	10
15	Phentolamine HCl	IM	1 mg/kg	6	Hypertension	53	0	2 8	-21	3 2	0	11
16	Tolazoline HCl	IV	20-100 mg	24	*Normotension*	59	-12	1.7	+6	3.6	-3	12
17				6	Mitral stenosis	45	+22	2.0	-25			13
	Other Hypotensive Drugs											
18	Alkavervir	IV	1 µg/kg/min	27	Hypertension	57	-12	3.2	-28	2.9	+17	14
19	Aminophylline	IV	0.5 g	10	Normal	59	-25	1.7	+24	3.8	0	15
20				16	Congestive heart failure	45	-33	2.6	+8	3 2	-18	16
21	Caffeine and sodium benzoate	IV	0.25-0.5 g	7	Hypertension	54	-13	2.7	+22	3 2	+9	17
22				9	Brain tumor	44	-13	2 1	+28	2.6	+8	18
23	Glyceryl trinitrate	SL	0.6 mg	6	*Mitral stenosis*	40	-8	2.5	+4	3 3	-3	13
24	Histamine	IV	0.7 mg	10	Normal	57	0	1.7	-30	3.2	+6	18
	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-17	3.7	0	19
									2	2.3	+4	18
										2.6	+23	20
28	[illegible]		mg						7	3.4	-3	21

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow /4/ Or IM, 1 mg/kg.

Part III: CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE: MAN (Continued)

	Drug	Route	Dose	Subjects No.	Subjects Condition	Cerebral Blood Flow[1] Control[2]	Cerebral Blood Flow[1] % Change	Cerebral Vascular Resistance Control[3]	Cerebral Vascular Resistance % Change	Cerebral O_2 Uptake Control[2]	Cerebral O_2 Uptake % Change	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
					Sympathomimetic Amines							
29	Amphetamine sulfate	IV	10 mg	2	Brain tumor	42	-2	2.5	+4	2.4	+4	19
30	Epinephrine	IV[5]	20-70 µg/min	7	Normal	50	+22	1.8	0	3.4	+23	22
31				15	Normal	66	-4	1.2	0	4.2	-3	23
32	Levarterenol bitartrate	IV[5]	6-23 µg/min	3	Normal	61	-8	1.6	+37	3.7	-5	22
33				13	Normal	61	-21	1.3	-3	4.0	-5	23
34				4	Normal	62	-12	1.6	+53	4.6	-15	24
35	Metaraminol bitartrate	IV infusion		7	Normal	58	-9	1.6	+50	3.4	-6	24
					Nervous System Depressants							
36	Chlorpromazine	IV	200 mg	7	Normal	41	-9	2.9	-24	2.4	+4	25
37	Ethyl alcohol	IV		8	Normal	52	+8	2.1	-14	2.9	-3	25
38			Plus chlorpromazine	6	Normal	49	-6	2.0	-25	2.2	-4	25
39		PO		13	Normal	68	-18	1.6	+12	3.8	-10	26
40			After antabus	10	Normal	54	+18	2.0	-35	3.2	+16	26
41	Insulin (hypoglycemia)			7	Schizophrenia	54	+11	1.6	-13	3.3	-21	27
42				7	Schizophrenia, in coma	54	+16	1.6	-6	3.3	-42	27
43	Procaine HCl	IS		17	Hypertension	52	-12	3.1	-16	3.3	-3	28
44		Stellate block		13	Normotension and hypertension	47	-2	2.5	+3	3.2	-3	29
45				23	Cerebral vascular disease	57	-6	2.2	+4	3.6	-6	30
46	Thiopental sodium	IV		8	Schizophrenia, under seminarcosis	54	-2			3.3	0	27
47				8	Normal, anesthetized	61	-25			3.6	-37	31
48				11	Normal, anesthetized	54	+11	1.6	-19	3.3	-36	32
					Miscellaneous Drugs							
49	Ammonium chloride	IV	0.3% (0.3 L)	7	Normal	66	-21	1.3	+23	4.2	+5	33
50	Corticotropin	PO	250-400 mg daily for 4 da	4	Various diseases	52	0	2.2	0	2.9	-14	34
51	Cyanocobalamin, plus liver extract			7	Pernicious anemia	91	-56	0.9	+177	2.2	+22	35
52	Desoxycorticosterone acetate	IV	50 mg	15	Normal	58	-5	1.5	+6	3.1	-13	36
53	Digitalis preparations, and diuretics			12	Congestive heart failure	52	-4	3.2	-9	3.1	+13	37
54	Heparin	IV	200 mg	11	Senile dementia	34	-3	3.4	0	2.6	+4	38
55	Nicotinic acid	IV	300-800 mg	20	Various diseases	54	+6	2.3	+4	3.4	-3	39

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow. /5/ Or IM, 1 mg

Part II: CORONARY BLOOD FLOW, VASCULAR RESISTANCE, AND CARDIAC O_2 UPTAKE: MAN, DOG, RABBIT (Concluded)

[10] Winbury, M.M., and D. M. Green. 1952. Am. J. Physiol. 170:555. [11] Eckenhoff, J. E., J. H. Hafkenschiel, and C. M. Landmesser. 1947. Ibid. 148:582. [12] West, J. W. Unpublished. [13] Rowe, G. G., J. H. Huston, G. M. Maxwell, A. B. Weinstein, H. Tuchman, and C. W. Crumpton. 1955. J. Clin. Invest. 34:696. [14] Leusen, I. R., and H. E. Essex. 1953. Am. J. Physiol. 172:226. [15] Hackel, D. B., S. M. Sancetta, and J. Kleinerman. 1956. Circulation, N. Y. 13:92.

Part III: CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE: MAN

Values are per cent change from control. Route: IM = intramuscular, IS = intraspinal, IV = intravenous, PO = oral, SL = sublingual. (+) = increased, (-) = decreased, (0) = no significant change. For a comprehensive review, see reference 43.

	Drug	Route	Dose	Subjects		Cerebral Blood Flow[1]		Cerebral Vascular Resistance		Cerebral O_2 Uptake		Reference
				No.	Condition	Control[2]	% Change	Control[3]	% Change	Control[2]	% Change	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
	Ganglion Blocking Drugs											
1	Azamethonium dibromide	IV	1-6 mg/min	5	Normotension	51	-8	2.0	-35	2.8	+7	1
2				9	Normotension	53	+12	1.5	-20	3.2	+10	2
3	Hexamethonium bromide or chloride	IV[4]	1-8 mg/min	9	Normotension	57	-30	1.9	-11	3.2	-12	3
4				8	Normotension	57	-26	1.8	-17	3.2	-9	1
5				7	Young; normotension	46	-33	1.9	-37	2.8	+4	4
6				10	Elderly; normotension	48	-39	1.7	-31	2.7	0	4
7				10	Head up 15°, normotension	53	-11	2.4	-45	3.3	+3	5
8				8	Essential hypertension	48	-39	2.4	-33	2.8	-4	4
9				7	Malignant hypertension	60	-42	3.0	-17	3.5	-11	4
10				13	Hypertension	55	-16	3.5	-28	3.6	-3	6
11				6	Hypertension	50	-4	3.2	-27	3.5	0	7
	Adrenergic Blocking Drugs											
12	Dihydroergocornine methanesulfonate	IM	0.5 mg	5	Normotension	60	-8	1.7	-12	3.8	-8	8
13				12	Hypertension	58	0	2.9	-31	3.5	+3	9
14	Phenoxybenzamine HCl	IV	0.5-0.7 mg/kg	7	Hypertension	48	-12	3.2	-31	3.6	-14	10
15	Phentolamine HCl	IM	1 mg/kg	6	Hypertension	53	0	2.8	-21	3.2	0	11
16	Tolazoline HCl	IV	20-100 mg	24	Normotension	59	-12	1.7	+6	3.6	-3	12
17				6	Mitral stenosis	45	+22	2.0	-25			13
	Other Hypotensive Drugs											
18	Alkavervir	IV	1 µg/kg/min	27	Hypertension	57	-12	3.2	-28	2.9	+17	14
19	Aminophylline	IV	0.5 g	10	Normal	59	-25	1.7	+24	3.8	0	15
20				16	Congestive heart failure	45	-33	2.6	+8	3.2	-18	16
21	Caffeine and sodium benzoate	IV	0.25-0.5 g	7	Hypertension	54	-13	2.7	+22	3.2	+9	17
22				9	Brain tumor	44	-13	2.1	+28	2.6	+8	18
23	Glyceryl trinitrate	SL	0.6 mg	6	Mitral stenosis	40	-8	2.5	+4	3.3	-3	13
24	Histamine	IV	0.7 mg	10	Normal	57	0	1.7	-30	3.2	+6	18
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-17	3.7	0	19
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-22	2.3	+4	18
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+3	2.6	+23	20
	[illegible]	[illegible]	mg	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-17	3.4	-3	21

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow /4/ Or IM, 1 mg/kg.

Part III. CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE: MAN (Concluded)

1.1148 [40] Patterson, J. L., Jr., A. Heyman, and F. T. Nichols. 1950. J. Clin. Invest. 29:1327. [41] Sokoloff, L., R. L. Wechsler, R. Mangold, K. Balls, and S. S. Kety. 1953. Ibid. 32:202. [42] Kety, S. S., and C. F. Schmidt. 1948 Ibid. 27:484. [43] Sokoloff, L. 1959. Pharm. Rev., Balt. 11:1.

Part IV. RENAL AND HEPATIC BLOOD FLOW AND VASCULAR RESISTANCE: MAN, DOG

Values are averages for reported number of cases and represent per cent change from control. Route: IM = intramuscular, IS = intraspinal, IV = intravenous, PO = oral. (+) = increase, (-) = decrease, (0) = no significant change.

	Drug	Route	Dose	Subjects			Blood Flow		Vascular Resistance[3]		Reference
				Animal	No	Condition	Renal[1]	Hepatic[2]	Renal	Hepatic	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
	Ganglion Blocking Drugs										
1	Azamethonium dibromide	IV	Hypotensive doses	Man	9	Normotension	-8		-12		1
2				Dog	8	Anesthetized	0		-23		2
3	Chlorisondamine dimethochloride	IV	0.3 mg/kg	Dog	16	Anesthetized	-4	-4	0	+	3
4	Hexamethonium bromide	IV, IM	Hypotensive doses	Man	9	Normotension	-21[5]		+10[5]		4
5				Man	9	Normotension	+17[6]		-55[6]		4
6				Man	17	Normotension		-33		+5	5
7				Man	6	Hypertension		-28			6
8				Man	5	Hypertension	-53				7
9				Man	8	Hypertension	-12				8
10				Man	7	Hypertension	+15		-28		9
11				Dog	20	Anesthetized	-11		-19		10
12				Dog		Anesthetized	-56[4]		+14		11
13	Mecamylamine HCl	IV	0.5-2 mg	Dog	17	Anesthetized	-21		0		12
14	Trimethaphan camphorsulfate	IV	[illegible]	[illegible]	[illegible]	[illegible]	+18		+33		13
15				[illegible]	[illegible]	[illegible]	[illegible] 4		+4		13
16				[illegible]	[illegible]	[illegible]	[illegible]		-36		2
17	Azapetine phosphate	IV	[illegible]	[illegible]	[illegible]	[illegible]					8
18	Hydergine	IV	0.6 mg	Man	6	Hypertension	-11				8
19				Dog	14	Anesthetized	+5		-8		14
20	Phenoxybenzamine HCl	IV	5-10 mg/kg	Dog	5	Anesthetized	+20		-50		15
21				Dog	8	Anesthetized	+57		-40		16
22				Dog	12	Anesthetized	+15		-32		17
	Other Antihypertensive Drugs										
23	Hydralazine	IV	0.25-1 mg/kg	Man	12	Normotension	+38				18
24				Man	8	Hypertension	+37				8
25				Man	6	Hypertension		+34		-41	19
26				Man	7	Toxemia of pregnancy	+9				20
27				Dog	6	Anesthetized	-30				21
28				Dog	17	Anesthetized		+58		-56	22
29	Protoveratrine	IV	100-200 µg	Man	15	Hypertension	-8				23
30				Man	3	Hypertension	-25		±		23
31				Man	8	Hypertension	-7				8
32	Reserpine	PO	2 mg daily for 3-5 mo	Man	15	Hypertension	0				24
33	Veratrone	IM	0.4-1.0 ml	Man	2	Hypertension	-	-	-	-	25
34				Dog	3	Anesthetized	-				26
	Musculotropic Vasodilators										
35	Aminophylline	IV	0.5 g	Man	10	Normal	+30[7]				27
36				Man	6	Cardiac failure	+12[7]				27
37	Ethyl alcohol	IV	25-81 mg % blood level	Man	5	Peptic ulcer		+45			28

/1/ Measured by p-aminohippurate renal clearance and blood hematocrit [2]. /2/ Measured by bromsulphalein hepatic clearance and blood hematocrit [22]. /3/ Ratio of mean arterial blood pressure to blood flow. /4/ Measured directly by insertion of rotameter in artery /5/ Immediate. /6/ 3 hours later. /7/ Temporary increase accompanied by prolonged diuretic action.

Part III: CEREBRAL BLOOD FLOW, VASCULAR RESISTANCE, AND O_2 UPTAKE: MAN (Continued)

	Drug	Route	Dose	Subjects		Cerebral Blood Flow[1]		Cerebral Vascular Resistance		Cerebral O_2 Uptake		Reference
				No.	Condition	Control[2]	% Change	Control[3]	% Change	Control[2]	% Change	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
	Miscellaneous Drugs (concluded)											
56	Penicillin, plus fever therapy			6	Meningovascular syphilis	39	+18	2.6	-11	2.5	+10	40
57	Sodium bicarbonate	IV	1.2% (1 L)	6	Normal	60	+30	1.6	-25	3.6	+8	33
58			3% (1 L)	10	Normal	52	+69	1.8	-39	3.6	-6	33
59	Sodium chloride	IV	0.9% (1 L)	6	Normal	60	0	1.7	-6	3.7	0	33
60			2% (1 L)	7	Normal	59	+12	1.5	-7	3.6	-8	33
61	Thiouracil iodine and surgery			11	Thyrotoxicosis	69	-13	1.6	+31	3.5	-14	41

/1/ Measured by nitrous oxide method of Kety and Schmidt [42]. /2/ ml/100 g/min. /3/ Ratio of mean arterial blood pressure to cerebral blood flow.

Contributors: Aviado, Domingo M., Jr., and Carl F. Schmidt

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Part IV. RENAL AND HEPATIC BLOOD FLOW AND VASCULAR RESISTANCE: MAN, DOG

Values are averages for reported number of cases and represent per cent change from control. Route: IM = intramuscular, IS = intraspinal, IV = intravenous, PO = oral. (+) = increase, (−) = decrease, (0) = no significant change.

	Drug	Route	Dose	Subjects: Animal	Subjects: No.	Subjects: Condition	Blood Flow: Renal[1]	Blood Flow: Hepatic[2]	Vascular Resistance[3]: Renal	Vascular Resistance[3]: Hepatic	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
	Ganglion Blocking Drugs										
1	Azamethonium dibromide	IV	Hypotensive doses	Man	9	Normotension	−8		+12		1
2				Dog	8	Anesthetized	0		−23		2
3	Chlorisondamine dimethochloride	IV	0.3 mg/kg	Dog	16	Anesthetized	−[4]	−[4]	0	*	3
4	Hexamethonium bromide	IV, IM	Hypotensive doses	Man	9	Normotension	−21[5]		+13[5]		4
5				Man	9	Normotension	+17[6]		−55[5]		4
6				Man	17	Normotension		−33		+4	5
7				Man	9	Hypertension		−23			6
8				Man	5	Hypertension	−59				7
9				Man	8	Hypertension	−12				8
10				Man	7	Hypertension	+15		−24		9
11				Dog	20	Anesthetized	−11		+13		11
12				Dog		Anesthetized	−56[4]		+19		1[illegible]
13	Mecamylamine HCl	IV	0.5–2 mg	Dog	17	Anesthetized	−21		0		13
14	Trimethaphan camphorsulfate	IV	1–13 mg/min	Man	9	Normotension	−19		+32		13
15				Man	8	Hypertension	−14		+4		13
16				Dog	9	Anesthetized	0		−30		2
	Adrenergic Blocking Drugs										
17	Azapetine phosphate	IV	5–10 mg	Man	8	Hypertension	−7				6
18	Hydergine	IV	0.6 mg	Man	6	Hypertension	−11				8
19				Dog	14	Anesthetized	+5		−8		14
20	Phenoxybenzamine HCl	IV	5–10 mg/kg	Dog	5	Anesthetized	+20		−50		13
21				Dog	8	Anesthetized	+57		−40		16
22				Dog	12	Anesthetized	+15		−32		17
	Other Antihypertensive Drugs										
23	Hydralazine	IV	0.25–1 mg/kg	Man	12	Normotension	+18				13
24				Man	8	Hypertension	+37				8
25				Man	6	Hypertension		+34		−41	19
26				Man	7	Toxemia of pregnancy	+9				20
27				Dog	6	Anesthetized	−10				2
28				Dog	17	Anesthetized		+28		+56	12
29	Protoveratrine	IV	100–200 µg	Man	15	Hypertension	−8				22
30				Man	3	Hypertension	−25		*		23
31				Man	8	Hypertension	−7				8
32	Reserpine	PO	2 mg daily for 3–5 mo	Man	15	Hypertension	0				24
33	Veratrone	IM	0.4–1.0 ml	Man	2	Hypertension	+	+	−	−	25
34				Dog	1	Anesthetized	−				26
	Musculotropic Vasodilators										
35	Aminophylline	IV	0.5 g	Man	10	Normal	+30[7]				27
36				Man	6	Cardiac failure	+27[7]				27
37	Ethyl alcohol	IV	25–81 mg % blood level	Man	5	Peptic ulcer		+45			23

/1/ Measured by p-aminohippurate renal clearance and blood hematocrit [2]. /2/ Measured by bromsulphalein hepatic clearance and blood hematocrit [22]. /3/ Ratio of mean arterial blood pressure to blood flow. /4/ Measured directly by insertion of rotameter in artery. /5/ Immediate. /6/ 3 hours later. /7/ Temporary increase accompanied by prolonged diuretic action.

Part IV: RENAL AND HEPATIC BLOOD FLOW AND VASCULAR RESISTANCE: MAN, DOG (Continued)

	Drug	Route	Dose	Subjects			Blood Flow		Vascular Resistance[3]		Refere
	(A)	(B)									
38	Histamine	IV									
						shock					
49											
50											
51											
52											
						shock					
53	Metaraminol bitartrate	IV	15 mg	Man	8	Normal	-4		+56		36
						anesthesia					
59				Man	5	High spinal anesthesia		-33		+7	44
60	Sodium chloride	IV	0.9% (1-3L)	Man	35	Normal	+4				45

/1/ Measured by p-aminohippurate renal clearance and blood hematocrit [2]. /2/ Measured by bromsulphalein hepatic clearance and blood hematocrit [22]. /3/ Ratio of mean arterial blood pressure to blood flow.

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Part V. PULMONARY ARTERIAL BLOOD PRESSURE, BLOOD FLOW, VASCULAR RESISTANCE, AND LOCAL EFFECT ON LUNG VESSELS: MAN, DOG

Values are averages for reported number of cases and represent per cent change from control. Route of administration is intravenous unless otherwise indicated. (+) = increase, (-) = decrease, (±) = increase or decrease, (0) = no significant change. Discrepancies between column (H) and column (I) are due to the fact that column (H) includes active changes in resistance caused by local action of drug plus passive changes caused by alteration in blood flow in man, whereas local effect on lung vessels was elicited from perfusion, at a constant flow, of dog or cat lung.

	Drug (A)	Dose (B)	Subjects: Animal (C)	Subjects: No. (D)	Subjects: Condition (E)	Pulmonary Arterial Pressure[1] (F)	Pulmonary Blood Flow[2] (G)	Pulmonary Vascular Resistance[3] (H)	Local Effect on Lung Vessels (I)	Reference[4] (J)
	Ganglion Blocking Drugs									
1	Hexamethonium bromide or chloride	15-50 mg	Man	10	Normal	-17	0	+21	None	1;2
2			Man	4	Mitral stenosis	-35	0	-35		3
3			Man	8	Pulmonary hypertension	-14	-16	+4		4
4	Tetraethyl-ammonium chloride or bromide	2-6 mg/kg	Man	5	Normal	-3	0	-3	None	5,2
5			Man	6	Mitral stenosis	-26	±	±		6
6			Man	5	Mitral stenosis	-26	+12	-35		7
7			Man	5	Left heart failure	-20	0	-20		8
8			Man	10	Cardiopulmonary diseases	-19	-32	-14		5
	Adrenergic Blocking Drugs									
9	Dibenamine HCl	0 5-2 mg/kg	Man	4	Mitral stenosis	-27	+7	-34	Unknown	7
10			Man	4	Left heart failure	-21	-6	-17		7
11	Dihydroergot-amine meth-anesulfonate	1 mg	Man	10	Normal	+28	0	+41	None	7,2
12			Man	8	Pulmonary diseases	+38	0	+45		9
13	Hydergine	0 3-0.5 mg	Man	9	Cardiopulmonary diseases	0	0	0	None	9;2
14	Tolazoline HCl	10-50 mg	Man	8	Pulmonary hypertension	-		-		10

[1] [illegible] ... semicolon pertain to [illegible]

Part V: PULMONARY ARTERIAL BLOOD PRESSURE, BLOOD FLOW, VASCULAR RESISTANCE, AND LOCAL EFFECT ON LUNG VESSELS: MAN, DOG (Continued)

	Drug	Dose	Subjects			Pulmonary Arterial Pressure[1]	Pulmonary Blood Flow[2]	Pulmonary Vascular Resistance[3]	Local Effect on Lung Vessels	Reference[4]
			Animal	No.	Condition					
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Sympathomimetic Amines									
15	Epinephrine	0.5-0.7 mg[5]	Man	13	Normal	+20	+30	*	Constrictor	11;12-16
16	Hydroxyamphetamine hydrobromide	2-20 mg	Dog	4	Unanesthetized	+			Variable	17;18
17	Isoproterenol HCl	0.25%[6]	Man	18	Bronchospasm	-			Dilator	19;20
18	Levarterenol bitartrate	0.2-0.4 µg/kg/min	Man	13	Cardiopulmonary diseases	+33	-6	0	Constrictor	21,16,22
19	Mephentermine sulfate	5-20 mg	Man	4	Normal	+	0	+	Dilator	23;18
20	Metaraminol bitartrate	0.65 mg	Man	7	Normal	+95	0	+	Constrictor	24,18
21	Methoxamine HCl	0.1 mg/kg	Dog	10	Anesthetized	-	-	-	Variable	25;18
22	Phenylephrine HCl	0.1-0.6 mg	Dog	14	Anesthetized	+70	-	+	Constrictor	26;18
	Cardiac Glycosides									
23	Digitalis, various preparations		Man	6	Low output failure	-40	+46	-		27
24	Digoxin	1-1.5 mg	Man	2	Pulmonary hypertension	+4	+7		None	28;29
25			Man	5	Cor pulmonale, not in failure	0	+15			28
26			Man	3	Cor pulmonale, in failure	+7	0			28
27			Man	5	Left heart failure	-	+25			30
28			Man	5	Congestive heart failure	-12	+29			31
29			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
					tension, compensated					
32			Man	4	Systemic hypertension, decompensated	-12	+33	-37		34
33			Dog	3	Unanesthetized	+				17
34	Procaine amide HCl	1 g	Man	10	Heart disease	-	-11		None	36;2
35	Procaine HCl[7]		Man	5	Low spinal anesthesia	-17	-16			37
36			Man	5	High spinal anesthesia	-34	-31			37
37	Sodium nitrite	40-60 mg	Man	4	Mitral stenosis	-10	+11	-19	Variable	7;2
38			Man	5	Left heart failure	-18	+10	-20		7
39	Veratrone	0.4-1.0 ml[5]	Man	2	Systemic hypertension, compensated	-10			None	38;2

/1/ Measured by catheter registering via an electrical manometer or mercury manometer /2/ Measured by indirect methods, such as Fick principle or dye dilution. /3/ Ratio of pressure gradient in pulmonary circulation to blood flow; pressure gradient calculated by assuming pulmonary venous pressure unchanged at zero, or by using wedged arterial pressure as pulmonary venous pressure. /4/ Reference numbers following semicolon pertain to column (I) only. /5/ Intramuscular. /6/ Inhalation. /7/ Intraspinal.

Part V: PULMONARY ARTERIAL BLOOD PRESSURE, BLOOD FLOW, VASCULAR RESISTANCE, AND LOCAL EFFECT ON LUNG VESSELS: MAN, DOG (Continued)

	Drug	Dose	Subjects			Pulmonary Arterial Pressure[1]	Pulmonary Blood Flow[2]	Pulmonary Vascular Resistance[3]	Local Effect on Lung Vessels	Reference[4]
			Animal	No.	Condition					
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Miscellaneous Drugs, Predominantly Pulmonary Hypotensive (concluded)									
41	Veratrine (concluded)	0.4-1.0 ml[5]	Man	3	Systemic hypertension, decompensated	-29				34
	Miscellaneous Drugs, Not Pulmonary Hypotensive									
42	Acetylcholine chloride	25-250 µg	Dog	3	Unanesthetized	*			Constrictor	17,2; 39
42	Amyl nitrite		Dog	4	Unanesthetized	0			Variable	17,29
43	Dextran	6% (500 ml in 20 min)	Man	5	Normal	+52	+36			40
44	Histamine phosphate	0.3-2 mg	Dog	3	Unanesthetized	+			Constrictor	17,41; 39
45	Hydralazine	0.2-0.5 mg/kg	Man	4	Normal	+45	+112	+27		42
46			Man	12	Mitral stenosis	+42	+34	+3		43
47			Man	11	Mitral stenosis	+18	+25			44
48			Man	17	Systemic hypertension	-9	+33	-24		45
49			Man	8	Systemic hypertension	+	+			46
50			Man	11	Systemic hypertension	0	+	-		47
51			Man	3	Toxemia of pregnancy	0	+31	-40		48
52	Khellin	100-200 mg[5]	Man	5	Pulmonary hypertension	-4	-4		None	49,2
53			Man	6	Chronic pulmonary diseases	0	0	0		50
54	Papaverine HCl	32-64 mg	Dog	4	Unanesthetized	+			Variable	17,29
55	Posterior pituitary extract	0.1 unit/kg	Dog	4	Unanesthetized	+			Variable	17,2
56			Dog	12	Anesthetized	+	-54	+		51
57	Serotonin	0.5 mg	Dog	25	Anesthetized	+	*	+50	Constrictor	52,53
58	Sodium chloride	0.9% (1 L in 12 min)	Man	12	Normal	+90	+19			54

/1/ Measured by catheter registering via an electrical manometer or mercury manometer. /2/ Measured by indirect methods, such as Fick principle or dye dilution. /3/ Ratio of pressure gradient in pulmonary circulation to blood flow; pressure gradient calculated by assuming pulmonary venous pressure unchanged at zero, or by using wedged arterial pressure as pulmonary venous pressure. /4/ Reference numbers following semicolon pertain to column (I) only. /5/ Intramuscular.

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Part V: PULMONARY ARTERIAL BLOOD PRESSURE, BLOOD FLOW, VASCULAR RESISTANCE, AND LOCAL EFFECT ON LUNG VESSELS: MAN, DOG (Continued)

	Drug	Dose	Subjects			Pulmonary Arterial Pressure[1]	Pulmonary Blood Flow[2]	Pulmonary Vascular Resistance[3]	Local Effect on Lung Vessels	Reference[4]
			Animal	No.	Condition					
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Sympathomimetic Amines									
15	Epinephrine	0.5-0.7 mg[5]	Man	13	Normal	+20	+30	±	Constrictor	11;12-16
16	*Hydroxyamphetamine hydrobromide*	*2-20 mg*	*Dog*	*4*	*Unanesthetized*	+			Variable	17,18
17	Isoproterenol HCl	0.25%[6]	Man	18	Bronchospasm	-			Dilator	19,20
18	Levarterenol bitartrate	0.2-0.4 µg/kg/min	Man	13	Cardiopulmonary diseases	+33	-6	0	Constrictor	21;16,22
19	Mephentermine sulfate	5-20 mg	Man	4	Normal	+	0	+	Dilator	23;18
20	Metaraminol bitartrate	0.65 mg	Man	7	Normal	+95	0	+	Constrictor	24;18
21	Methoxamine HCl	0.1 mg/kg	Dog	10	Anesthetized	-	-	-	Variable	25;18
22	Phenylephrine HCl	0.1-0.6 mg	Dog	14	Anesthetized	+70	-	+	Constrictor	26;18
	Cardiac Glycosides									
23	Digitalis, various preparations		Man	6	Low output failure	-40	+46	-		27
24	Digoxin	1-1.5 mg	Man	2	Pulmonary hypertension	+4	+7		None	28,29
25			Man	5	Cor pulmonale, not in failure	0	+15			28
26			Man	3	Cor pulmonale, in failure	+7	0			28
27			Man	5	Left heart failure	-	+25			30
28			Man	5	Congestive heart failure	-12	+29			31
29			Man	12	Enlarged heart	-7	+9			32
30	Lanatoside C	1.4 mg	Man	6	Mitral stenosis	±	+	-	None	33;29
	Miscellaneous Drugs, Predominantly Pulmonary Hypotensive									
31	Aminophylline	0.5 g	Man	7	Systemic hypertension, compensated	-25	+6	+4	Dilator	34;35
32			Man	4	Systemic hypertension, decompensated	-12	+33	-37		34
33			Dog	3	Unanesthetized	+				17
34	Procaine amide HCl	1 g	Man	10	Heart disease	-	-11		None	36,2
35	Procaine HCl[7]		Man	5	Low spinal anesthesia	-17	-16			37
36			Man	5	High spinal anesthesia	-34	-31			37
37	Sodium nitrite	40-60 mg	Man	4	Mitral stenosis	-10	+11	-19	Variable	7;2
38			Man	5	Left heart failure	-18	+10	-20		7
39	Veratrone	0.4-1.0 ml[5]	Man	2	Systemic hypertension, compensated	-10			None	38;2

/1/ Measured by catheter registering via an electrical manometer or mercury manometer. /2/ Measured by indirect methods, such as Fick principle or dye dilution. /3/ Ratio of pressure gradient in pulmonary circulation to blood flow; pressure gradient calculated by assuming pulmonary venous pressure unchanged at zero, or by using wedged arterial pressure as pulmonary venous pressure. /4/ Reference numbers following semicolon pertain to column (I) only. /5/ Intramuscular. /6/ Inhalation. /7/ Intraspinal.

Part V. PULMONARY ARTERIAL BLOOD PRESSURE, BLOOD FLOW, VASCULAR RESISTANCE, AND LOCAL EFFECT ON LUNG VESSELS MAN, DOG (Continued)

	Drug	Dose	Subjects			Pulmonary Arterial Pressure[1]	Pulmonary Blood Flow[2]	Pulmonary Vascular Resistance[3]	Local Effect on Lung Vessels	Reference[4]
			Animal	No.	Condition					
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Miscellaneous Drugs, Predominantly Pulmonary Hypotensive (concluded)									
40	Veratrone (concluded)	0.4-1.0 ml[5]	Man	3	Systemic hypertension, decompensated	-29				38
	Miscellaneous Drugs, Not Pulmonary Hypotensive									
41	Acetylcholine chloride	25-250 µg	Dog	3	Unanesthetized	±			Constrictor	17,2, 39
42	Amyl nitrite		Dog	4	Unanesthetized	0			Variable	17;29
43	Dextran	6% (500 ml in 20 min)	Man	5	Normal	+50	+36			40
44	Histamine phosphate	0.3-2 mg	Dog	3	Unanesthetized	+			Constrictor	17,41, 39
45	Hydralazine	0.2-0.5 mg/kg	Man	4	Normal	+45	+110	+27		42
46			Man	10	Mitral stenosis	+40	+38	+3		43
47			Man	11	Mitral stenosis	+16	+25			44
48			Man	17	Systemic hypertension	-9	+33	-28		45
49			Man	8	Systemic hypertension	+	+			46
50			Man	11	Systemic hypertension	0	+	-		47
51			Man	3	Toxemia of pregnancy	0	+31	-60		48
52	Khellin	100-200 mg[5]	Man	5	Pulmonary hypertension	-4	-6		None	49,2
53			Man	6	Chronic pulmonary diseases	0	0	0		50
54	Papaverine HCl	32-64 mg	Dog	4	Unanesthetized	+			Variable	17,29
55	Posterior pituitary extract	0.1 unit/kg	Dog	4	Unanesthetized	+			Variable	17;2
56			Dog	10	Anesthetized	+	-54	+		51
57	Serotonin	0.5 mg	Dog	25	Anesthetized	+	±	+50	Constrictor	52,53
58	Sodium chloride	0.9% (1 L in 10 min)	Man	12	Normal	+66	+19			54

/1/ Measured by catheter registering via an electrical manometer or mercury manometer. /2/ Measured by indirect methods, such as Fick principle or dye dilution. /3/ Ratio of pressure gradient in pulmonary circulation to blood flow; pressure gradient calculated by assuming pulmonary venous pressure unchanged at zero, or by using wedged arterial pressure as pulmonary venous pressure. /4/ Reference numbers following semicolon pertain to column (I) only. /5/ Intramuscular

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Part V: PULMONARY ARTERIAL BLOOD PRESSURE, BLOOD FLOW, VASCULAR RESISTANCE, AND LOCAL EFFECT ON LUNG VESSELS. MAN, DOG (Concluded)

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Part VI: LIMB BLOOD FLOW AND LOCAL EFFECT ON LIMB VESSELS: MAN, DOG

less otherwise specified, data are for man. Route: IM = intramuscular, IS = intraspinal, IV = intravenous, PO = ıl, SC = subcutaneous. Local effect on limb vessels elicited by direct arterial injection into intact limb or into rfused limb.

Drug	Route	Dose	Subjects		Blood Flow[1]	Local Effect on Limb Vessels	Reference
			No.	Condition			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
Ganglion Blocking Drugs							
Azamethonium dibromide	IV	0.6-1.3 mg/kg	10	Peripheral vascular disease	Increased	None	1
Chlorisondamine dimethochloride	PO	100 mg	4	Hypertension	Increased		2
Hexamethonium bromide or chloride	IV	5-100 mg	22	Hypertension	Increased	None	3-6
			10	Heart failure	Not increased		7

/ Determined by skin temperature of fingers or toes, or by limb plethysmography.

111. HEMODYNAMIC EFFECTS OF DRUGS. MAMMALS (Continued)

Part VI. LIMB BLOOD FLOW AND LOCAL EFFECT ON LIMB VESSELS MAN, DOG (Continued)

	Drug	Route	Dose	Subjects No.	Subjects Condition	Blood Flow[1]	Local Effect on Limb Vessels	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Ganglion Blocking Drugs (concluded)							
5	Pentamethonium chloride	IV	0.3-0.7 mg/kg	14	Peripheral vascular disease	Increased	None	8
6	Tetraethyl-ammonium bromide or chloride	IV	200-500 mg	14	Normal	Increased	Variable	9
7				11	Peripheral vascular disease	Increased		10
	Adrenergic Blocking Drugs							
8	Azapetine phosphate	IV	5-10 mg	8	Hypertension	Increased		5
9	Dihydroergocornine methanesulfonate	IV	0.25-1 mg	34	Normal	Increased	Weak constrictor	11,12
10				6	Hypertension	Increased		13
11				20	Various diseases	Increased		14
12	Hydergine	IV	0.6 mg	8	Hypertension	Increased	Weak constrictor	5
13	Phenoxybenzamine HCl	PO	20-480 mg daily	16	Peripheral vascular disease	Increased		15,16
14	Phentolamine HCl	IM	0 6-0.75 mg/kg	5	Normal	Increased	Dilator	17
15				4	Peripheral vascular disease	Increased		17
16				13	Peripheral organic occlusion	Increased		17
17	Roniacol tartrate	IV	30-50 mg	30	Pregnant	Unchanged		18
18	Tolazoline HCl	IM, IV	30-50 mg	10	Normal	Increased	Dilator	17,19, 20
19				16	Peripheral vascular disease	Increased		21
	Other Vasodilators							
20	Atropine sulfate	IM	2 mg	73	Normal	Increased	Dilator	22
21	Ethyl alcohol	PO		5	Peripheral vascular disease	Increased	Dilator	10
22	Histamine diphosphate	Femoral arterial injection		8	Peripheral vascular disease		Dilator	23
23	Hydralazine	IV	0 25-0.5 mg/kg	12	Normotension	Unchanged	Weak dilator	24
24				14	Hypertension	Decreased		5,25
25	Isoproterenol HCl	IV	2-20 µg/min	9	Normal	Increased	Dilator	26,27
26	Methacholine chloride	SC	3-5 mg	3	Peripheral vascular disease	Unchanged	Dilator	10
27	Nicotinic acid	PO	50-100 mg	8	Peripheral vascular disease	Decreased	Dilator	10
28	Pentobarbital sodium	IV	35 mg/kg	8[2]	Anesthetized	Increased[3]	Dilator	28
29	Tubocurarine chloride	Femoral arterial injection		28[2]	Anesthetized		Dilator	29,30
	Miscellaneous Drugs							
30	Epinephrine	IV	10 µg/min	22	Normal	Increased	Constrictor and dilator[4]	31-34
31	Levarterenol bitartrate	IV	10-20 µg/min	8	Normal	Unchanged	Constrictor	26,34

/1/ Determined by skin temperature of fingers or toes, or by limb plethysmography. /2/ Dogs. /3/ Measured by appropriate flowmeters attached to vessels of hind limbs. /4/ Dependent on dosage and on nature of reactive vascular bed, i.e., skin or muscle.

	Drug	Route	Dose	Subjects		Blood Flow[1]	Local Effect on Limb Vessels	Reference
				No.	Condition			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Miscellaneous Drugs (concluded)							
32	Procaine HCl	IV	250-500 mg	9	Normal	Decreased	Dilator	35
33				9	Peripheral vascular disease	Variable		35
34		IS	250-500 mg	5	Low spinal anesthesia	Decreased[5]		36
35				5	High spinal anesthesia	Increased[5]		36
36	Protoveratrine	IV	100-170 µg	25	Hypertension	Increased	None	37
37				8	Hypertension	Unchanged		5
38	Veratrone	IM	0.4-1.0 ml	2	Hypertension	Decreased	None	38

/1/ Determined by skin temperature of fingers or toes, or by limb plethysmography. /5/ Hand blood flow.

Contributors: Aviado, Domingo M., Jr., and Carl F. Schmidt

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112. EFFECT OF DRUGS ON CARDIAC PROPERTIES

oses are not indicated [illegible] (in situ and excised) were used. Specific doses may be ound by consulting the [illegible] initiate impulses spontaneously dioventricular rhythm [illegible] arrhythmia as a esult of mechanical, e. [illegible] lar muscle): time equired after effective contraction for the muscle [illegible] o transmit a propagated wave an effective distance; measurements made either on animal heart [illegible] ed heart muscle strips. Conduction time (atrial or ventricular muscle): time required for an impulse to travel from one point to another, measurements made on isolated heart muscle strips. Conduction time (A-V system): measured by PR [illegible] ECG. Rate (sino-atrial node): measured by ECG of intact animals. Contractility (total heart): measured [illegible] heart in situ [34,75], or by muscle lever tied to apex of isolated, perfused [illegible] A-V system = atrioventricular conduction system (atrial muscle, [illegible] f the bundle of His).

	Drug (A)	[illegible]ponent (B)	Property (C)	Effect (D)	Reference (E)
	Antiarrhythmic or Antifibrillatory Drugs Clinically Useful				
1	Ambonestyl HCl	Ventricular muscle	Ectopic automaticity	Depressed	1
2			Refractory period	Prolonged	1
3	Procaine amide HCl	Total heart	Contractility	Decreased	2
4		Sino-atrial node	Rate	Accelerated[1]	2
5		Atrial muscle	Ectopic automaticity	Depressed	3
6			Refractory period	Prolonged	2
7		A-V system	Conduction time	Prolonged	3,4
8		Ventricular muscle	Automaticity	Depressed	2
9			Ectopic automaticity	Depressed	1,4
10			Refractory period	Unchanged	2
11			Conduction time	Prolonged	3,4
12	Procaine HCl	Total heart	Contractility	Decreased	2
13		Sino-atrial node	Rate	Accelerated[1]	2
14		Atrial muscle	Ectopic automaticity	Depressed	5
15		Ventricular muscle	Ectopic automaticity	Depressed	6,7
16	Quinidine sulfate	Total heart	Contractility	Decreased	2
17		Sino-atrial node	Rate	Accelerated[1]	2
18		Atrial muscle	Ectopic automaticity	Depressed	8
19			Refractory period	Prolonged	8-13
20			Conduction time	Prolonged[2]	12,13
21		A-V system	Conduction time	Shortened[1]	2
22		Ventricular muscle	Automaticity	Depressed	2
23			Ectopic automaticity	Depressed	13,14
24			Refractory period	Prolonged	11
25			Conduction time	Prolonged	8,15
	[illegible]al Use)				
26	Chloraquin[illegible]	[illegible]	[illegible]	[illegible]	16,17
27		[illegible]	[illegible]	[illegible]	17
28		[illegible]	[illegible]	[illegible]	18
29		[illegible]	[illegible]	[illegible]	17
30		[illegible]	[illegible]	[illegible]	17
31	Dibenami[illegible]	[illegible]	[illegible]	[illegible]	10
32	Dihydroe[illegible] methanesulfonate	[illegible]	[illegible]	[illegible]	19
33	Diphenhydramine HCl	Atrial muscle	Refractory period	Prolonged	20,21
34		Ventricular muscle	Ectopic automaticity	Depressed	22
35	Diphenylhydantoin sodium	Ventricular muscle	Ectopic automaticity	Depressed	23,24
36	α-Fagarine	Atrial muscle	Ectopic automaticity	Depressed	5
37			Refractory period	Prolonged	5,9
38			Conduction time	Prolonged	5,25
39	Glyceryl trinitrate	Total heart	Contractility	Increased	26
40		Ventricular muscle	Ectopic automaticity	Depressed	27
41	Meperidine HCl	Ventricular muscle	Ectopic automaticity	Depressed	28
42	Papaverine HCl	Atrial muscle	Refractory period	Prolonged	9
43		A-V system	Conduction time	Prolonged	5
44		Ventricular muscle	Ectopic automaticity	Depressed	14
45	Phentolamine HCl	Ventricular muscle	Ectopic automaticity	Depressed	29
46	Quinacrine HCl	Atrial muscle	Ectopic automaticity	Depressed	16,30
47		Ventricular muscle	Ectopic automaticity	Depressed	31
48	Tolazoline HCl	Ventricular muscle	Ectopic automaticity	Depressed	28

/1/ Vagolytic /2/ Vagolytic, plus direct action on heart muscle.

	Drug (A)	Heart Component (B)	Property (C)	Effect (D)	Reference (E)
	Heart Muscle Stimulants				
49	Aminophylline	Total heart	Contractility	Increased	2
50		Sino-atrial node	Rate	Accelerated	2
51	Amphetamine sulfate	Total heart	Contractility	Increased	32
52		Sino-atrial node	Rate	Accelerated	2
53	Atropine sulfate	Sino-atrial node	Rate	Accelerated[1]	2
54		Atrial muscle	Ectopic automaticity	Depressed[1]	33
55			Refractory period	Prolonged[1]	2
56			Conduction time	Prolonged[1]	2
57		A-V system	Conduction time	Shortened	2
58		Ventricular muscle	Refractory period	Prolonged	11
59			Ectopic automaticity	Depressed	11
60	Caffeine citrate	Total heart	Contractility	Increased	34
61		Sino-atrial node	Rate	Accelerated	2
62	Cardiac glycosides	Total heart	Contractility	Increased	34-37
63		Sino-atrial node	Rate	Decelerated	2
64		Atrial muscle	Refractory period	Shortened or prolonged[3]	2
65			Conduction time	Shortened or prolonged[3]	2
66		A-V system	Refractory period	Prolonged[3]	2
67			Conduction time	Prolonged[3]	2
68		Ventricular muscle	Automaticity	Increased	38, 39
69			Ectopic automaticity	Enhanced or depressed	2
70			Refractory period	Shortened	2
71			Conduction time	Prolonged	2
72	Ephedrine sulfate	Total heart	Contractility	Increased or decreased	34
73		Sino-atrial node	Rate	Accelerated	2
74	Epinephrine	Total heart	Contractility	Increased	2
75		Sino-atrial node	Rate	Decelerated[4] or accelerated	2
76		Atrial muscle	Refractory period	Shortened	40
77		A-V system	Conduction time	Shortened or prolonged[4]	41
78		Ventricular muscle	Automaticity	Increased	2
79			Ectopic automaticity	Depressed or enhanced	14
80			Refractory period	Shortened	11
81	Isoproterenol HCl	Sino-atrial node	Rate	Accelerated	42, 43
82		Ventricular muscle	Automaticity	Increased	42, 44
83			Ectopic automaticity	Unchanged	45
84	Levarterenol bitartrate	Sino-atrial node	Rate	Decelerated[4] or accelerated	32, 46-48
85		Ventricular muscle	Automaticity	Unchanged	44, 49
86			[illegible]		44, 49
87	Mephentermine sulfate	Total hear			32
88	Methamphetamine HCl	Total hear			32
89		Ventricula			50
90	Phenylpropanolamine HCl	Total hear			32
91	Phenylpropylmethylamine	Total hear			32
92	Sodium lactate[5]	Total heart			51
93		Ventricular			52
94	Tuaminoheptane sulfate	Total heart			32
95		Ventricular			53
96	Acetylcholine chloride	Sino-atrial		Decelerated or accelerated[6]	54
97		Atrial muscle	Ectopic automaticity	Enhanced	55
98			Refractory period	Shortened	40, 56
99			Conduction time	Shortened	2
100		A-V system	Conduction time	[illegible]	2
101		Ventricular			11
102					11
103	Aconitine	Atrial musc			57
104	Barium chloride	Total heart			34
105		Ventricular			58, 59
106	β-Dihydrosolasodine[7]	Sino-atrial r			60

/1/ Vagolytic. /3/ Direct action, plus increased vagal tone. /4/ Deceleration due to reflex increase in vagal tone arising from increase in arterial pressure. /5/ Molar solution. /6/ Acceleration due to reflex inhibition of vagal tone arising from fall in arterial pressure. /7/ Antagonizes cardio-accelerator action of epinephrine.

112. EFFECT OF DRUGS ON CARDIAC PROPERTIES (Continued)

	Drug (A)	Heart Component (B)	Property (C)	Effect (D)	Reference (E)
	Miscellaneous Drugs (concluded)				34
107	Calcium chloride	Total heart	Contractility	Increased	61,62
108		A-V system	Conduction time	Prolonged	63
109		Ventricular muscle	Ectopic automaticity	Enhanced	64
		Ventricular muscle	Ectopic automaticity	Depressed	65
			automaticity	Depressed	54
				Decelerated or accelerated[6]	55
			ticity	Enhanced	40,56
			iod	Shortened	2
			Conduction time	Shortened	2
114			tion time	Prolonged	11
				ease	11
					66
				ase	67
					32
					68
					61,69
				ase or enhanced	15
					70
				eased	71
				eased	72
				lerated	73
				anced	74
				lerated	
					75
			Contractility	eased	58
130	Chloroform[8]	Total heart			
131		Ventricular muscle	Ectopic automaticity	Enhanced	76
132	Cyclopropane[8]	Total heart	Contractility	Decreased	58
133		Ventricular muscle	Ectopic automaticity	Enhanced	75-77
134	Ether	Total heart	Contractility	Decreased	78,79
135		Ventricular muscle	Ectopic automaticity	Depressed	76,80
136	Nitrous oxide	Total heart	Contractility	Decreased	2
137	Phenobarbital sodium	Total heart	Contractility	Decreased	23
138		Ventricular muscle	Ectopic automaticity	Depressed	76
139	Thiopental sodium	Total heart	Contractility	Decreased	79
140		Ventricular muscle	Ectopic automaticity	Unchanged	81
		Ventricular muscle	Ectopic automaticity	Enhanced	82
	thylene			Decreased	75

easure. /7/ Antagonizes cardio-accelerator action of epinephrine /8/ ... arrhythmia for testing anti-arrhythmic activity of other drugs

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113 EFFECT OF INORGANIC IONS ON THE HEART: MAN, DOG

Data are for man, unless dog is specified. Normal serum concentration of sodium (Na^{+}) = 137-145 mEq/L [42, 43], normal serum sodium levels antagonize, and decreased sodium levels enhance, the deleterious effects of potassium on the electrocardiogram [8, 9, 36, 37]. The combination of hypopotassemia and hypocalcemia is difficult to recognize in the electrocardiogram [46] The administration of either potassium or calcium corrects only the electrocardiographic abnormality due to the deficiency of that particular electrolyte, without affecting the changes due to the deficiencies of the other electrolyte [1, 51]. The electrocardiogram is not a reliable tool for the measurement of electrolyte disturbance [46-48].

	Specification	Effect of Serum Concentration of Inorganic Ions: Calcium (Ca^{++})[1] Increased Ions	Calcium Decreased Ions	Magnesium (Mg^{++})[2] Increased Ions	Magnesium Decreased Ions	Potassium (K^{+})[3] Increased Ions[4]	Potassium Decreased Ions[5]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Systolic interval	Prolonged.	None.	None		Shortened.	Normal or shortened.	B,1,2;C,3,D,4;F,2,G,1
2	Diastolic interval	Shortened	Prolonged			Prolonged.		B,C,F,2
3	P wave and PR interval	Flattening or inversion of P wave, prolonged PR interval (transient)	Normal.	In man, slight prolongation may occur (not of diagnostic value clinically), prolonged in dog		P waves decrease in height, increase in duration; PR interval may be prolonged.	PR interval may be prolonged; increase in amplitude and width of P waves.	B,5,6,C,7,D,4,F,8-11;G,12
4	QRS duration	Normal.	Normal	Widened in dog.		May be wide, bizarre, diphasic; intraventricular block.	Occasionally increased.	B,C,F,7;D,4;F,8-10,13;G,7
5	QT interval	Shortened due to shortening of ST segment (not of diagnostic value clinically).	Prolonged due to lengthening of ST segment.		Shortened in dog.	May be shortened, unchanged, or lengthened, later QT is prolonged.	Normal; U waves become prominent, giving a prolonged QU interval.	B,3,5,14,C,1,3,14-16;E,17;F,11;G,1,11
6	ST segment[6]	Shortened or absent.	Prolonged		Sagging.	Depressed in precordial leads; elevated in cavity leads and occasionally elevated in precordial leads.	Progressive depression.	B,3,5,14,C,7,14,18,E,19;F,20,21,G,1,7,10,22
7	T wave[6]	Normal, flat, or inverted	Normal.	Inconstant minor variations.	Low in standard and left precordial leads.	"Tent-shaped"; tall, narrow, steep, pointed.	Broadened, rounded, low, inverted.	B,6,C,3,15,23,D,24;E,19,F,8,9-11,13,18,25,26,G,1,7,22,23,27

/1/ Normal = 4.5-5.5 mEq/L (9-11 mg %). [42, 43] /2/ Normal = 1.5-2.0 mEq/L (1.8-2.4 mg %). [44, 45] /3/ Normal = 3.5-5.0 mEq/L. /4/ Electrocardiographic changes are estimated to occur in 80-100% of subjects with blood levels of potassium above 6.8 mEq/L [23, 46]. Serum potassium may be elevated without definite electrocardiographic evidence of potassium intoxication [25, 47]. /5/ Electrocardiographic changes are estimated to occur in 80% of subjects with blood levels of potassium below 3.5 mEq/L, and in 100% of subjects with potassium levels below 2.3 mEq/L [23, 46]. Potassium deficiency may occur without recognizable electrocardiographic changes, or the pattern of potassium intoxication may appear [23, 47-50]. /6/ Pre-existent abnormalities of the ST segment and T wave may modify abnormalities induced by electrolyte disturbance [25, 51, 52].

113. EFFECT OF INORGANIC IONS ON THE HEART: MAN, DOG (Concluded)

	Specification	Effect of Serum Concentration of Inorganic Ions						Reference
		Calcium (Ca^{++})1		Magnesium (Mg^{++})2		Potassium (K^+)3		
		Increased Ions	Decreased Ions	Increased Ions	Decreased Ions	Increased Ions4	Decreased Ions5	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
8	U wave	Increased height.	Decreased height.		Prominent, but not large.	Decreased height.	Increased height; may become tall and pointed; increase in amplitude in left precordial leads.	B,C,F,28;E,19;F,28; G,1,28
9	Rate and rhythm	Bradycardia; later tachycardia, sinus arrhythmia, atrioventricular conduction defects, ventricular tachycardia or fibrillation may occur following calcium infusions.	Tachycardia.	Tachycardia initially and then bradycardia in dog; slowing may occur in man; occasional sinoatrial and atrioventricular block.	Tachycardia in dog.	First degree atrioventricular block, idioventricular rhythm; premature ventricular beats; ventricular tachycardia; ventricular and atrial fibrillation; sinus arrest; ventricular standstill.	Supra-ventricular tachycardia may occur; various arrhythmias may occur in digitalized subjects with low potassium.	B,6,11,29,30;C,16; D,4,31,32; E,17;F,8,9,11,15,20,33,34; G,11
10	Remarks	When serum calcium exceeds 6.5 mEq/L (13 mg %), the QT_c interval and ST segment are always shortened; when serum calcium is 3.0 mEq/L (6 mg %) or less, the QT_c interval and ST segment are always prolonged.	Normal serum calcium levels antagonize, and decreased calcium levels enhance, the deleterious effects of excess potassium on the electrocardiogram.7	Cardiac arrest rarely precedes respiratory arrest, changes not diagnostic in man; inconstant, transient variations in QRS amplitudes.	In dog, no consistent electrocardiographic changes attributed to magnesium depletion.	Disturbed depolarization, terminal slur in QRS or S wave in lead 1 or V_6 is frequent in early hyperpotassemia. Progressive hyperpotassemia causes peaking of T waves (at about 6.5 mEq/L), then widening of "S-ST" angle, QRS broadening with delay in activation of base of right ventricle, disturbance of rhythm, and the "sine" wave of ventricular fibrillation.	Disturbed repolarization; U waves may be prominent.	B,14;C,25,35-39;D,24,31;E,17;F,4,10,20,40,41; G,7,10,22

/1/ Normal = 4.5-5.5 mEq/L (9-11 mg %). [42, 43] /2/ Normal = 1.5-2.0 mEq/L (1.8-2.4 mg %). [44, 45] /3/ Normal = 3.5-5.0 mEq/L. /4/ Electrocardiographic changes are estimated to occur in 80-100% of subjects with blood levels of potassium above 6.8 mEq/L [23, 46]. Serum potassium may be elevated without definite electrocardiographic evidence of potassium intoxication [25, 47]. /5/ Electrocardiographic changes are estimated to occur in 80% of subjects with blood levels of potassium below 3.5 mEq/L, and in 100% of subjects with potassium levels below 2.3 mEq/L [23, 46]. Potassium deficiency may occur without recognizable electrocardiographic changes, or the pattern of potassium intoxication may appear [23, 47-50]. /7/ These findings have not been confirmed in recent studies [41].

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114. EFFECT OF INORGANIC IONS ON CARDIAC PROPERTIES

(+) = increased, (-) = decreased, (0) = no effect or unknown.

	Cardiac Property	Effect of: Calcium (Ca^{++}) Increased	Calcium (Ca^{++}) Decreased	Magnesium (Mg^{++}) Increased	Magnesium (Mg^{++}) Decreased	Potassium (K^{+}) Increased	Potassium (K^{+}) Decreased	Sodium (Na^{+}) Increased	Sodium (Na^{+}) Decreased
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Automaticity	-	0	-	0	-	0	0	+
2	Conductivity	0	0	-	0	-	0	0	0
3	Contractility	+	0	-	0	0	0	0	-
4	Excitability	+	-	-	0	-	0	0	0
5	Relaxation	-	0	+	0	+	0	0	+
6	Rhythm	+	0	-	0	-	0	0	+

Contributor. Gertler, Menard M.

115. ION RATIO REQUIRED TO MAINTAIN BEAT OF ISOLATED HEART: INSECTS

	Ion Ratio	Insect	Stage	Optimal Ratio	Reference
	(A)	(B)	(C)	(D)	(E)
1	Na^{+}.K^{+}	Calliphora	Larva	8:33.3	1
2		Chortophaga	Nymph and adult	3·34	2
3		Samia	Pupa	0.07.34	2
4		Galleria	Larva	8:16	3
5		Gryllus		8:16	4
6		Periplaneta	Nymph and adult	3 30	5
7		Tenebrio	Larva	1.4·32.4	6
8			Pupa	2.2.8.8	6
9			Adult	0.8:14.2	6
10	K^{+}:Ca^{++}	Chortophaga	Nymph and adult	1:3	2
11		Samia	Pupa	1:3	2
12		Periplaneta	Nymph and adult	0 9:3.5	5
13		Tenebrio	Larva	1:3	6
14			Pupa	1·3	6
15			Adult	1:3	6

Contributor: Ludwig, Daniel

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116. EFFECT OF CHEMICAL SUBSTANCES ON THE HEART: INSECTS

Effect differs with time, temperature, pretreatment, relation to other chemicals, concentration, type of preparation, type of pacemaker tissue, stage of development, age, nutritional status. In many cases, specific concentrations were not available. Consult references for details.

Part I. INORGANIC IONS

	Ion	Insect[1]	Stage	Salt Concentration in Perfusion Fluid[2]	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Calcium	Anopheles[3]	Larva	Excessive	No effect or stimulates	1
2		Chortophaga	Nymph and adult	Excessive	Inhibits	2
3		Cossus	Larva	Excessive	Stimulates	3
4		Culex[3]	Larva	Excessive	Stimulates	4
5		Samia	Pupa	Excessive	No effect or inhibits	2
6		Galleria	Larva	Excessive	Inhibits	5
7		Galleria	Larva	Reduced	Stimulates	5
8		Galleria	Larva	Absent	Stoppage in diastole	5
9	Magnesium	Anopheles[3]	Larva	Excessive	Inhibits	1
10		Chortophaga	Nymph and adult	Isotonic $MgCl_2$	Inhibits	2
11		Culex[3]	Larva	Excessive	Inhibits	4
12		Samia	Pupa	Isotonic $MgCl_2$	Inhibits	2
13	Potassium	Anopheles[3]	Larva	Excessive	Stimulates	1
14		Calliphora	Larva	Excessive	Stimulates	6
15		Calliphora	Larva	Reduced	Inhibits	6
16		Calliphora	Larva	Absent	Inhibits	6
17		Chortophaga	Nymph and adult	Isotonic KCl	Inhibits	2
18		Cossus	Larva	Excessive	Inhibits	3
19		Culex[3]	Larva	Excessive	Stimulates	4
20		Samia	Pupa	Isotonic KCl	No effect	2
21		Galleria	Larva	Excessive	Stops in systole	5
22		Galleria	Larva	Excessive	Inhibits	7
23		Galleria	Larva	Reduced	Inhibits	5
24		Galleria	Larva	Absent	Stoppage in diastole	5
25		Gryllus	Nymph and adult	Excessive	Stoppage in systole	8
26		Phormia	Larva	Excessive	Stimulates	6
27		Phormia	Larva	Reduced	Inhibits	6
28		Phormia	Larva	Absent	Inhibits	6
29		Tenebrio	Larva, pupa, adult	Excessive	No effect	9
30	Sodium	Anopheles[3]	Larva	Excessive	No effect or stimulates	1
31		Chortophaga	Nymph and adult	Isotonic NaCl	Inhibits	2
32		Cossus	Larva	Reduced	Inhibits	3
33		Culex[3]	Larva	Excessive	Stimulates	4
34		Samia	Pupa	Isotonic NaCl	No immediate effect	2
35		Tenebrio	Larva, pupa, adult	Excessive	No effect	9
36		Tenebrio	Larva, pupa, adult	Reduced	No effect	9

/1/ Unless otherwise indicated, heart exposed by dissection, then perfused /2/ "Excessive" varies from 2-10 x isotonic concentration /3/ Intact specimen totally immersed in solution.

Contributor Jones, Jack Colvard

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Part II: DRUGS AND TOXIC COMPOUNDS

	Substance	Insect	Stage	Condition	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
1	Acetylcholine	Anopheles	Adult		No effect.	1,2
2		Apis			Acceleration.	3
3		Blatta			Acceleration.	3
4		Galleria			No effect.	4
5		Melanoplus			Acceleration.	5
6		Periplaneta			Acceleration.	6,7
7		Stenopelmatus			Acceleration.	8
8	Adrenalin	Anopheles	Larva		Slight stimulation.	1
9		Anopheles	Adult	Intact	No effect.	1
10		Cossus		Intact	Acceleration.	9
11		Culex		Intact	Acceleration.	10
12		Periplaneta			Acceleration.	6,7
13		Stenopelmatus			Depression.	8
14	Aldrin	Periplaneta	Adult		Rate increased.	11
15	Anabasine sulfate	Blatta orientalis	Larva	Intact	Transient effects.	12
16		Pieris brassicae	Larva	Dissected	Instant arrest.	12
17		Pteronus	Larva	Intact	Submersion caused transient increase in rate, normal in 30 min. Rate increased fourfold when compound applied with brush; recovery after 4-hr paralysis.	12
18	Antimycin A	Periplaneta	Adult	Intact	Marked decrease in amplitude, diastolic arrest.	13
19	Atropine	Anopheles	Larva		Depression.	2
20		Anopheles	Adult	Intact	No effect; did not block [illegible]	1
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] nicotine effects.	[illegible]
26	BHC (Benzene hexachloride)	Allomyrina dichotomus			No marked effect after prolonged perfusion.	15
27		Locusta migratoria danica	Larva	Dissected	No marked effect.	16
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] diastolic arrest.	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] effects.	[illegible]
36		Stenopelmatus			No marked effect, did not modify acetylcholine effects.	8
37	DDT (Dichlorodiphenyltrichloroethane)	Anopheles	Larva	Intact	No effect prior to convulsions at concentration of 10^{-5}, eserine and atropine had no effect on rate.	18
38		Corethra	Larva	Partially dissected	Rate decreased with doses of 1 1000 to 1 10,000 in 1.5% NaCl emulsions.	19
39		Drosophila	Larva	Intact	Rate increased when DDT first injected, then returned to normal.	20

Part II · DRUGS AND TOXIC COMPOUNDS (Continued)

	Substance	Insect	Stage	Condition	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
40	DDT (Dichlorodiphenyl-trichloroethane) (concluded)	*Locusta migratoria danica*	Larva	Dissected	Rate greatly decreased and irregular with spasms of body and alary muscles; heart not stimulated by low concentration of acetylcholine after prolonged perfusions.	16
41		Periplaneta	Adult	Intact	Heart beat after extremities stopped twitching.	21
42		Periplaneta	Adult	Intact	No immediate effect; diastolic arrest.	17
43		Periplaneta	Adult	Intact	Rate decreased slightly.	22
44		Periplaneta	Adult	Dissected	No effect for 5-7 min at concentration of 10^{-5}, irregular beat later, previous atropine treatment had no effect	7
45		Stenopelmatus	Adult	Dissected	No effect in 5% emulsion, heart beat at reduced rate for hours in 100 ppm.	8
46	Dieldrin	Anopheles	Larva	Intact	No marked primary effects.	18
47		Periplaneta	Adult	[illegible]	Rate increased.	11
48	Digitalis	Anopheles	Adult	[illegible]	[illegible]	[illegible]
49		Corethra	[illegible]	[illegible]	[illegible]	[illegible]
50		Periplaneta	[illegible]	[illegible]	[illegible]	[illegible]
51	Diphtheria toxin	Hyalophora	Pupa	[illegible]	[illegible] massive dose.	[illegible]
52	DNOC (4,6-Dinitro-o-cresol), DNOCHP (Dinitro-o-cyclohexylphenol)	Periplaneta	Adult	Intact	Rate increased significantly; when substance first injected, posterior heart showed temporary stoppage in diastole.	17
53	DNP (Dinonylphthalate)	Anopheles	Larva	Intact	Rate increased greatly at concentrations of 10^{-2} to 10^{-3}; no effect at concentrations of 10^{-4} to 10^{-5}.	18
54	EPN (Ethyl p-nitrophenyl thionobenzenephosphate)	Anopheles	Larva	Intact	Rate increased with larval agitation.	18
55	Ergotamine	Periplaneta			Stimulation, then depression.	7
56	Eserine	Anopheles			No marked effect.	1
57		Culex	Adult	Intact	Stimulation.	10
58		Oncopeltus			No effect.	24
59		Periplaneta			Stimulation.	7
60		Stenopelmatus			No marked effect, potentiated acetylcholine effects.	8
61	Hexamethonium	Periplaneta			No effect.	7
62	Lethane 60 (mixed aliphatic thiocyanates)	Periplaneta	Adult	Intact	Injection caused slight rate increase, followed by gradual decrease; diastolic arrest.	17
63	Lethane 384 (mixed aliphatic thiocyanates)	Periplaneta	Adult	Intact	3% dilution caused sharp decrease, irregular beat, death. 1.25% resulted in sharp decrease, rise above normal, recovery.	25
64	Lindane (1,2,3,4,5,6-Hexachlorocyclohexane)	Periplaneta			Irregular beat.	17
65	Lobeline	Periplaneta			Stimulation with low concentrations, depression with high concentrations.	6
66	Mecholyl	Anopheles			No effect.	2
67	Methoxychlor	Anopheles	Larva	Intact	No marked primary effects.	18

Part II· DRUGS AND TOXIC COMPOUNDS (Continued)

	Substance	Insect	Stage	Condition	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
68	Morphine	Anopheles	Adult		Depression.	1
69		Periplaneta			Stimulation with low concentrations, depression with high concentrations.	6
70	Muscarine	Stenopelmatus			No effect.	8
71	Nicotine	Anopheles			No marked effect.	1
72		Culex		Intact	Stimulation with low concentrations, depression with high concentrations.	10
73		Culex		Intact	Depression.	26
74		Melanoplus			Rate temporarily increased, then decreased.	5
75		Periplaneta			Irregular decline.	25
76		Periplaneta			Stimulation with low concentrations, depression with high concentrations.	6, 7, 27
77		Prodenia			Initial stimulation followed by partial depression, extent depending on concentration.	27
78		Stenopelmatus			Acceleration.	8
79	Para-oxon	Periplaneta	Adult	Dissected	No effect at concentration of 3×10^{-6}, rate increased immediately then declined at concentration of 15×10^{-7}; blocked by atropine.	7
80	Parathion	Corethra	Larva	Partially dissected	Rate increased.	19
81		[illegible]	Adult	Intact	Rate increased.	17
82						17
83					... increased steadily with irradiated parathion; blocked atropine; potentiated acetylcholine effects.	7
84	Phenothiazine	Anopheles	Larva	Intact	No marked primary effects.	18
85		Corethra	Larva	Intact	Beats continued for 3 wk.	28
86	Pilocarpine	Anopheles			No marked effect.	1, 2
						6
						29
						23
						29
[illegible]	[illegible]				... more than 5 da.	30
92		Corethra	Larva	Intact	Rate decreased	28
93		Corethra	Larva	Intact	Normal during initial convulsions; rate decreased slightly after 1 da, decreased markedly after several da	31
94		Galleria	Larva	Dissected	Anterior heart stopped first in diastole	32
95		Lymantria	Larva	Intact	Weak beats continued more than 5 da	30
96		Periplaneta	Adult	Intact	Sublethal dose caused rate increase, lethal dose caused continuous decrease.	25
97		Periplaneta	Adult	Dissected	Prolonged rate increase at concentration of 10^{-8}, atropine abolished effect.	7

Part II. DRUGS AND TOXIC COMPOUNDS (Continued)

	Substance	Insect	Stage	Condition	Effect	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
98	Pyrethrum (concluded)	Vanessa	Larva	Intact	Weak beats continued for more than 5 da	30
99	Rotenone	Allomyrina dichotomus			Temporary increase in rate and decrease in amplitude; subsequent rate decrease and irregularities.	15
100		*Anopheles*	Larva	Intact	No marked primary effects.	18
101		*Bombyx*	Larva	Intact	Rate decreased 10-15 min before other symptoms appeared	33
102		Culex	Larva	Intact	Rate decreased.	33
103		Dendrolimus	Larva	Intact	Beats continued 6 da.	30
104		Periplaneta	Nymph and adult	Intact	Injection or contact caused steady rate decrease; anterior heart stopped first in diastole.	17, 33
105		Periplaneta	Nymph and adult	Intact	Heart stopped in 26-42 min.	22
106		Periplaneta	Nymph and adult	Dissected	Rate decreased to cessation in diastole.	7, 34
107		Plutella	Larva	Intact	Rate decreased.	33
108		Tomato cutworm	Larva	Intact	Rate decreased	33
109		Vanessa	Larva	Intact	Beats continued for 6 da.	30
110	Sodium arsenite and arsenate	Bombyx	Larva	Intact	Injection caused transient rate decrease; contact caused slow decrease.	35
111	Sodium fluoride	Anopheles	Larva	Intact	Transient rate increase, then decrease.	36
112	Sodium metarsenite	Anopheles	Larva	Intact	Rate decreased.	18
113	Strychnine	Culex		Intact	Stimulation.	10
114		Periplaneta			Stimulation with low concentrations, depression with high concentrations.	6
115	TEPP (Tetraethyl pyrophosphate)	Periplaneta	Adult	Intact	Beats occurred in prostrate roach.	36
116		Periplaneta	Adult	Dissected	0.02% dilution caused decreased rate, systolic arrest, concentration of 8×10^{-8} resulted in sharply increased rate and amplitude.	34
117	Thiocyanate	Blatta orientalis	Adult	Dissected	Dilatation from increased myotonus of alary muscles, rate decreased.	37
118	Toxaphene	Anopheles	Larva	Intact	No effect in 30 min at concentration of 10^{-4}.	18
119		Periplaneta	Adult	Intact	Rate irregular; stoppage in diastole.	17
120	Veratrine	*Corethra*			Slightly stimulating effects.	14

Contributors (a) Jones, Jack Colvard, (b) Ludwig, Daniel, (c) Beard, Raimon L., (d) Dresden, D, and A. Glenn Richards, (e) Brown, A. W. A

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Part II: DRUGS AND TOXIC COMPOUNDS (Concluded)

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Part III GASES AND VAPORS

All specimens intact.

	Gas or Vapor	Insect	Stage	Effect	Reference
	(A)	(B)	(C)	(D)	(E)
1	Acetone	Macrosiphum tulipae		Heart stopped in 10 min.	1
2	Benzene	Macrosiphum tulipae		Heart stopped in 8 min.	1
3	Carbon dioxide	Anopheles	Larva	100% concentration caused diastolic arrest in 30 sec-3 min; normal rate following anesthesia.	2
4		Anopheles	Larva	5% concentration stimulated heart rate.	2
5		Corethra	Larva	Irregularities.	3
6		Grasshopper		Beat continued for 6 hr; isolated heart stopped in 20-60 sec.	4
7		Oncopeltus		Heart stopped rapidly.	5
8	Carbon disulfide	Macrosiphum tulipae		Heart stopped in 4-7 min.	1
9	Carbon monoxide	Corethra	Larva	Brief stimulation.	3
10		Grasshopper		No recovery after 48-hr exposure.	4
11	Carbon tetrachloride	Macrosiphum tulipae		Heart stopped in 13 min.	1
12	Chloroform	Macrosiphum tulipae		Heart stopped in 5-10 min.	1
13	Cyanide	Calliphora	Larva	Heart rate declined rapidly following 30-min exposure.	6
14		Periplaneta		Heart rate declined sharply following 1-hr exposure, then rose above normal.	7
15	Ether	Anopheles	Larva	No effect after 20-min exposure to 1/2-saturated aqueous solution.	2
16		Grasshopper		No effect during 3-hr exposure; isolated heart stopped in 1 min.	4
17	Ethyl acetate plus chloroform (2:1 ratio)	Macrosiphum tulipae		Heart stopped in 11 min.	1
18	Formaldehyde, 40%	Macrosiphum tulipae		Heart stopped in 57 min.	1
19	Hydrogen	Grasshopper		Beat continued for 5 da, isolated heart beat up to 4 da.	4
20	Nitrobenzene	Macrosiphum tulipae		Heart stopped in 50 min.	1
21	Nitrogen	Anopheles	Larva	99% concentration caused rapid decline in 1 hr	2
22	Oxygen	Anopheles	Larva	1-100% concentration had no effect or caused only slight stimulation.	2

Contributors (a) Jones, Jack Colvard, (b) Ludwig, Daniel

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Data are for substances translocated predominantly in the phloem. Translocation of antibiotics in plants has not been included, as much of the data indicates acropetal movement chiefly within the transpiration stream or xylem. *Translocation rates*, where given, do not necessarily represent maximum or even mean values for the conditions of the experiment, for in many cases they are simply based on the time interval between treatment and harvest or assay of specific plant parts. In most instances, where the rate is based on time of absorption from cuticular surface to phloem, the true translocation rate within the phloem will be greater than the figures given. It is known, of course, that many organic substances applied to a plant are broken down into different metabolic products within the plant. Recent research (made possible largely by chromatography) indicates, however, that at least a significant portion of most organic materials is translocated within the plant in the exact molecular form in which applied. For simplification of tabulation, the organic materials appearing in the substance column are listed as they were applied to the plant, i.e., before metabolic change. Direction pertains only to the given experiment, and may vary according to growth stage, concentration of translocated substance, and other conditions; A = acropetal, B = basipetal.

Part I ASSIMILATES AND CARBOHYDRATES

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Ash, white (Fraxinus americana)	Trunk	Mannitol, raffinose, stachyose, sucrose, verbascose		B	Transport of specific substances determined by chromatography of sieve tube exudate obtained from cut in bark. Concentration gradient of individual sugars varied with height in tree, but overall molar gradient was zero after leaf abscission.	1,2
2	Bean (Phaseolus vulgaris)	Leaf, stem	Carbohydrates		A/1/, B/1,2/	Application of 2,4-D to various loci along primary leaf midveins reduced carbohydrate and dry matter accumulation in aerial parts, as determined by analysis 9-29 da later. Application to leaf tips less effective than to leaf center or pulvinus.	3
3		Leaf	Starch, sugars		B	Starch and sugar analysis of leaf blades, with petiole maintained at 1-25°C (maximum translocation at 25°). Encasing petioles with N_2 inhibited translocation	4
4		Leaf	Sugars		B	Increased translocation of sugars resulting from application of boron may be due to element's tendency to decrease enzymatic conversion of glucose-1-phosphate to starch. Increased synthesis of sucrose or other hexose phosphates from resultant glucose-1-phosphate may cause the increased translocation.	5
5		Leaf, stem	Fructose, glucose, sucrose	107	A/1/, B/1,2/	C^{14} activity in various constituents of stem determined by autoradiography after application of C^{14}-labelled CO_2 to 1 leaflet. P^{32} and THO, applied simultaneously with C^{14}, were translocated at a slower rate. Concentration gradient of THO within stem was different from that of C^{14} and P^{32}.	6,7
6		Leaf, stem	Sucrose		A/1/, B/3/	Solution applied to 1 primary leaf, with petiole maintained at 5-40°C (maximum translocation at 20-30°). Subsequent apical growth in dark measured Retarding effect of low temperatures decreased with time.	8

/1/ Stem /2/ Leaf /3/ Petiole.

Part I: ASSIMILATES AND CARBOHYDRATES (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
7	Bean (Phaseolus vulgaris) (concluded)	Leaf, stem	Sucrose		A[1], B[3]	Solution applied to 1 primary leaf, with petiole maintained at fluctuating temperatures in 12-hr cycles: 25° and 5°, 40° and 25°, and 25°C continuous (maximum translocation). Stem elongation, during 81-hr period in dark, measured.	9
8		Leaf, stem	Photosynthate		A, B	One primary leaf exposed to C^{13}-labelled CO_2; active photosynthate determined in various plant parts.	10
9		Leaf, stem	Photosynthate, sucrose		A[1], B[1,3]	Hypocotyls maintained at 7-40°C (maximum translocation at 33°). Plants placed either in light, or in dark with 1 primary leaf in solution. Apical growth measured over period of 115 hr.	11
10	Bean (Phaseolus vulgaris) Beet, sugar (Beta vulgaris) Cotton (Gossypium sp) Plantain (Plantago sp) Pumpkin (Cucurbita pepo)	Leaf, stem, root, fruit	Sucrose, hexose phosphates	30-100	A[1], B[1,2]	Autoradiography and radiochromatography of isolated vascular bundles, after application of C^{14}-labelled sugar or CO_2 to beet leaves, showed sucrose to be the dominant sugar. Presence of phosphorylase and phosphatase, and of sugar-phosphate esters in other plants, suggested esters as being an important translocatory form along with sucrose. In pumpkin, translocation rate greatest in young plants, and greater in basipetal direction than in acropetal.	12-14
11	Bean (Phaseolus vulgaris) Milkweed (Asclepias syriaca) Tomato (Lycopersicon esculentum)	Leaf	Soluble sugars, starch		B	Change in carbohydrate content and dry weight of matched pairs of leaves, both excised and intact, during 13-hr dark period Temp. = 4-40°C (maximum translocation at 20-30°)	15
12	Bean (Phaseolus vulgaris) Tomato (Lycopersicon esculentum)	Leaf, stem, root	Sucrose		A, B	C^{14} activity in stem tip and roots determined 4-24 hr after submersion of lower leaf in C^{14}-labelled solution. Addition of 10 ppm boron to solution increased activity in tip by 550% in tomato.	16
13	Beet, sugar (Beta vulgaris)	Leaf, stem, root	Fructose, glucose, sucrose		A, B	Chemical analysis of plant parts. Translocation only out of mature leaves, but could take place into young leaves	17
14		Leaf, stem, root	Glucose, sucrose	2-3	A, B	Application of C^{14}-labelled glucose or sucrose to 4 basal leaves. Movement to youngest leaf and roots determined by autoradiogram· activity in specific sugars noted by radiochromatogram. Temp = 26°C.	18

/1/ Stem. /2/ Leaf. /3/ Petiole.

117. TRANSLOCATION OF ORGANIC SUBSTANCES. PLANTS (Continued)

Part I. ASSIMILATES AND CARBOHYDRATES (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
15	Beet, sugar (Beta vulgaris) (concluded)	Leaf, stalk, root	Sucrose, mono-saccharides	70-100	B	Sucrose was first free sugar formed during photosynthesis. It penetrated vascular bundles and moved to lower stalk and root more rapidly than mono-saccharides, as determined by radiochromatography.	19,20
16		Leaf, stem, root	Reducing sugars, sucrose		B	Chemical analysis of different sugars in various plant parts and tissues. Reducing sugars apparently polymerized into sucrose in leaf phloem.	21
17	Cotton (Gossypium sp)	Stem	Total sugars	2-3	B	Chemical analysis of tissue in isolated and semi-isolated flaps of stem phloem under various conditions Temp. = 26°C.	22
18	Cucumber (Cucumis sativus) Pumpkin (Cucurbita pepo)	Peduncle	Assimilates	14	Into fruit	Rate of movement based on calculations of sap flow required to develop full-size cucumber (based on exudation rate of cut peduncles), and from cross-sectional area of phloem. Temp. = 2-24°C.	23
19	Geranium (Pelargonium hortorum)	Leaf, stem	Photosynthate		A, B	C^{14}-labelled CO_2 applied to leaf above stem section with phloem separated from xylem, and $KH_2P^{32}O_4$ applied to leaf below section. Simultaneous movement of C^{14} and P^{32} in opposite directions through separated phloem. Temp = 28-29°C.	24
20	Grape, concord (Vitis labruscana)	Leaf, cane	Sucrose	60	A[1], B[1,2]	Radiochemical analysis at various loci along cane, after application of C^{14}-labelled CO_2 to single leaf, indicated sucrose to be only translocated sugar. The fructose and glucose found were apparently hydrolytic products of the translocatory sucrose.	25
21	Hornbeam (Carpinus betulus) Locust, black (Robinia pseudoacacia) Wax plant (Hoya carnosa)	Leaf	Sucrose			Sucrose, but no monosaccharides or sugar phosphates, identified in phloem exudate by chromatography. Presence of phosphorylated compounds in bundle sheath suggested splitting and synthesis into sucrose before entering phloem.	26
22	Kelp, giant (Macrocystis pyrifera)	Stipe	Photosynthate		A, B	Translocation into youngest leaves and basal holdfast determined from measurements of photosynthesis, respiration, and dry weight change of blades at various levels. Temp. = 19-21°C.	27
23	Maize (Zea mays)	Leaf, stalk	Primarily sucrose		A, B	Translocation from leaves to grain during period of development shown by chemical analysis of various plant parts.	28

/1/ Stem /2/ Leaf.

Part I ASSIMILATES AND CARBOHYDRATES (Continued)

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
7	Bean (*Phaseolus vulgaris*) (concluded)	Leaf, stem	Sucrose		A[1], B[3]	Solution applied to 1 primary leaf, with petiole maintained at fluctuating temperatures in 12-hr cycles: 25° and 5°, 40° and 25°, and 25°C continuous (maximum translocation). Stem elongation, during 81-hr period in dark, measured.	9
8		Leaf, stem	Photosynthate		A, B	One primary leaf exposed to C^{13}-labelled CO_2; active photosynthate determined in various plant parts.	10
9		Leaf, stem	Photosynthate, sucrose		A[1], B[1,3]	Hypocotyls maintained at 7-40°C (maximum translocation at 33°). Plants placed either in light, or in dark with 1 primary leaf in solution. Apical growth measured over period of 115 hr.	11
10	Bean (*Phaseolus vulgaris*) Beet, sugar (*Beta vulgaris*) Cotton (*Gossypium* sp) Plantain (*Plantago* sp) Pumpkin (*Cucurbita pepo*)	Leaf, stem, root, fruit	Sucrose, hexose phosphates	30-100	A[1], B[1,2]	Autoradiography and radiochromatography of isolated vascular bundles, after application of C^{14}-labelled sugar or CO_2 to beet leaves, showed sucrose to be the dominant sugar. Presence of phosphorylase and phosphatase, and of sugar-phosphate esters in other plants, suggested esters as being an important translocatory form along with sucrose. In pumpkin, translocation rate greatest in young plants, and greater in basipetal direction than in acropetal.	12-14
11	Bean (*Phaseolus vulgaris*) Milkweed (*Asclepias syriaca*) Tomato (*Lycopersicon esculentum*)	Leaf	Soluble sugars, starch		B	Change in carbohydrate content and dry weight of matched pairs of leaves, both excised and intact, during 13-hr dark period Temp. = 4-40°C (maximum translocation at 20-30°).	15
12	Bean (*Phaseolus vulgaris*) Tomato (*Lycopersicon esculentum*)	Leaf, stem, root	Sucrose		A, B	C^{14} activity in stem tip and roots determined 4-24 hr after submersion of lower leaf in C^{14}-labelled solution. Addition of 10 ppm boron to solution increased activity in tip by 550% in tomato.	16
13	Beet, sugar (*Beta vulgaris*)	Leaf, stem, root	Fructose, glucose, sucrose		A, B	Chemical analysis of plant parts. Translocation only out of mature leaves, but could take place into young leaves.	17
14		Leaf, stem, root	Glucose, sucrose	2-3	A, B	Application of C^{14}-labelled glucose or sucrose to 4 basal leaves. Movement to youngest leaf and roots determined by autoradiogram. activity in specific sugars noted by radiochromatogram. Temp. = 26°C.	18

/1/ Stem. /2/ Leaf. /3/ Petiole.

Part I: ASSIMILATES AND CARBOHYDRATES (Continued)

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
34	Soybean (Glycine max)	Leaf, stem	Fructose, glucose, sucrose	84	A, B	C^{14}-labelled CO_2, applied to 1 leaf during photosynthesis, recovered 20 min later in sucrose and invert sugars of apical portion of stem. Treatment of single leaflet did not result in appreciable movement to other leaflets. Temp. = 26-30°C.	40,41
35		Leaf, stem, root	Fructose, glucose, photosynthate, sucrose	90	A[1], B[1,2]	C^{14}-labelled sucrose or glucose, applied to primary leaf, was translocated more in dark than in light. Sugar uptake was increased by boron and sodium dodecyl sulfate.	42
36		Leaf, stem, root	Fructose, glucose, photosynthate, sucrose	100[4], 300[5]	A[1], B[1,2]	Translocation of C^{14}-labelled sugars applied to leaf was increased by boron and surfactant. With hexoses, activity in stem decreased logarithmically from introduction point, with sucrose, it decreased linearly. Hexoses passed killed stem sections, but were impeded at nodes, sucrose did not pass killed sections, and was not impeded at nodes.	43,44
37		Leaf, stem, root, nodule	Photosynthate		B	Chromatographic analysis of nodules and root tissue 1 da, or 1 da and 1 night, after application of C^{14}-labelled CO_2 to foliage. Distribution of C^{14} in amino acids, organic acids, and carbohydrates different in nodules and root tissue, and different in the 2 harvest periods	45
38		Cotyledon	Reducing sugars, total sugars		From cotyledon	Chemical analysis of cotyledons showed sugars to have nearly disappeared by emergence (10 da). K and P were also exported rapidly, followed by ether-extractables and proteins.	46
39	Squash (Cucurbita pepo)	Peduncle	Assimilates	8-177	Into fruit	Phloem exudate collected hourly over 24-hr period. Rates, generally decreasing with time, based on exudate collected and observed cross-sectional area of sieve tubes or phloem. Later data indicated that N_2 content of phloem exudate was higher than N_2 content of fruit, relative to C content. Phloem exudate may, therefore, not be precisely identical to true assimilate stream. Temp. = 20-32°C.	47,48
40	Sugar cane (Saccharum officinarum)	Leaf, stem, root	Photosynthate	43	B	C^{14}-labelled CO_2 applied to 1 leaf. Activity detected in roots after 6 hr, and in sister shoot of same plant after 20 hr.	49

/1/ Stem /2/ Leaf. /4/ Old seedlings. /5/ Young seedlings.

Part I. ASSIMILATES AND CARBOHYDRATES (Continued)

Plant	Part	Substance	Translocation		Remarks	Reference
			Rate cm/hr	Direction		
(A)	(B)	(C)	(D)	(E)	(F)	(G)
Maize (Zea mays) (concluded)	Shoot, root	Photosynthate		B	Activity of various substances in shoot and root determined after 24 hr of photosynthesis in atmosphere of C^{14}-labelled CO_2. Maximum activity in carbohydrates, organic and amino acids, with less activity in pigments, fat, protein, starch, and cellulose.	29
Molds, black, blue, green (Aspergillus flavus, A. niger, A. oryzae, Penicillium notatum, Rhizopus nigricans, R. oryzae)	Mycelium	Glucose, sucrose (also nitrogen, phosphorus, fluorescein)		Unidirectional	Translocation determined by ability of a mold to grow from a full-nutrient agar into a deficient agar. Positive ability (Rhizopus only) associated with protoplasmic streaming. Visual observation corroborated by chemical analysis.	30
Oak, red (Quercus rubra) Other broad-leaved trees	Trunk	Assimilates, sugars	10-200	B	Determinations of sugar content of sap at heights between 1.5 and 12.5 m at various time intervals of day and night, and measurement of exudation rates.	31,32
Palm, date (Phoenix dactylifera)	Peduncle, trunk	Assimilates		Into fruit	Increment in pericarp dry weight, measured at 6 a.m. and 6 p m on consecutive days, indicated approximately 10 times more assimilate translocated into fruit during night than during day.	33
Pea (Pisum sativum)	Leaf	Assimilates		B	Change in weight of matched pairs of leaflets, both excised and intact, during growth in light or a 15-hr dark period Translocation at 10°C as great as, or greater than, that at 20°C.	34
Pea (Pisum sativum) Potato (Solanum tuberosum)	Leaf	Photosynthate		B	Measurement of photosynthesis, respiration, and dry weight change of pea leaves indicated maximum export during afternoon. Potato showed maximum export during night.	35
Potato (Solanum tuberosum)	Rhizome	Soluble carbohydrates	40	Into tuber	Calculated rate based on assumed movement of 10% solution in phloem, cross-sectional area of which was measured.	36
Pumpkin, Connecticut field Squash, early prolific straightneck	Peduncle	Assimilates	55-160	Into fruit	Translocation rate calculated from increment in dry weight of fruit at various stages of development, from observed cross-sectional area of peduncle sieve tube lumina, and from 10-20% concentration of assimilates therein	37
Raspberry (Rubus idaeus)	Stem	Reducing sugars, starch, sucrose		A, B	Both reducing sugars and sucrose translocated, but sucrose accumulated to a greater degree above stem girdle.	38
Sausage tree (Kigelia africana)	Peduncle	Sugars		Into fruit	The 1.75% sugar content of flowing sap is seemingly too low a concentration to account for growth rate of fruit on assumption of a mass flow hypothesis.	39

Part I. ASSIMILATES AND CARBOHYDRATES (Concluded)

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Part I· ASSIMILATES AND CARBOHYDRATES (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
41	Sugar cane (Saccharum officinarum) (concluded)	Leaf, stalk, root	Photosynthate	43	$A^{1,2}$, $B^{1,2}$	Translocation of C^{14}-labelled CO_2 recovered from entire plant 18 hr after application to 5th leaf, and respired labelled CO_2 recovered from roots 6 hr after application. C^{14}-labelled CO_2 recovered from 16 stalks of a single stool 44 hr after application to a leaf of 1 stalk.	50
42	Sunflower, mammoth Russian (Helianthus sp)	Cotyledon, stem	Sucrose		A^1, $B^{1,6}$	Translocation of C^{14}-labelled sucrose from cotyledon to stem was not influenced by addition of boron or germanium. This and other data suggest boron does not affect sugar transport through formation of a boron-sugar complex.	51
43	Tomato (Lycopersicon esculentum)	Cotyledon, leaf, stem	Assimilates		A, B	Dry weight changes in individual leaves, both intact and separated. Greatest translocation during day, with movement generally from cotyledons and older leaves to younger leaves.	52
44		Leaf, stem	Sucrose		B	Chemical analysis of leaves and accumulation of sucrose above stem girdle Temp. = 18-26°C (maximum translocation at 18°).	53
45		Leaf, stem, root	Sucrose	3-4	B	Translocation of foliar-applied sucrose into roots inferred by increased bleeding rate from cut stump, occurred 8-12 hr after sucrose application. Stems held at 1-23°C (maximum translocation at 1°).	54
46		Leaf, stem	Sucrose		A^1, B^3	Elongation of stem and apical leaf during 110 hr in dark while basal leaf was immersed in sucrose solution. Petioles or stems maintained at 12-30°C (maximum translocation at 24°).	55
47		Leaf, stem	Photosynthate, sucrose		A^1, $B^{1,2}$	C^{14} activity decreased logarithmically up and down stem from node of leaf supplied with C^{14}-labelled CO_2, transport being reduced in boron-deficient plants. Boron added to C^{14}-labelled sucrose increased its translocation	56
48	Wheat (Triticum sp)	Leaf, stem, seed	Photosynthate		A^1, $B^{1,2}$ into seed	Analysis of seed at intervals, after application of C^{14}-labelled CO_2 to leaves, indicated more rapid translocation in irrigated areas than in water-deficient areas. Transport from awns accounted for 12% of total kernel dry weight accumulation from 2nd through 4th week after heading	57,58

/1/ Stem. /2/ Leaf. /3/ Petiole. /6/ Cotyledon.

Contributor: Hull, Herbert M

Part II: DYES (Concluded)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
9	Geranium (Pelargonium sp)	Leaf, stem	Fluorescein	1-30	A[2], B[1,2]	Applied in gelatin block to scarified leaf or stem surface, subsequent movement through sieve tube protoplasm microscopically observed with ultraviolet light. Most rapid movement in young leaves. Measurements at 1-30°C (maximum translocation at 20-30°).	10
10	*(P. zonale)*	Leaf	Sodium fluorescein, rhodamine B and other dyes	0-2	A, B	Applied to incision on ventral petiole surface, 1 cm below blade. Movement through sieve tube observed microscopically for 3 hr in dark, humid chamber, with petiole maintained at temperatures of 2-21°C (maximum translocation at 21°). Variation from other findings perhaps due to shorter *time of* movement and length of translocation path, different pH and osmotic pressure of solutions, delay in *entrance* from wound to sieve tube.	11
11		Leaf	Potassium fluorescein (also N and P compounds)			Translocation of dye and N compounds in *petiole* sieve tubes not affected by N_2, H_2, or CO, but reversibly inhibited by HCN. Inhibition less *intense* with *P* compounds, suggesting independent movement. Transport apparently dependent on a respiratory process.	12
12	Pumpkin (Cucurbita sp)	Leaf	Potassium fluorescein		A, B	Artificially reversing (by osmosis) polar streaming in sieve tube vacuoles caused simultaneous bidirectional movement in external and internal phloem. Transport apparently passive in streaming solution of the vacuoles, and only secondarily drawn into the cytoplasm.	13

/1/ Petiole. /2/ Stem.

Contributor: Hull, Herbert M.

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Part II: DYES

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Apple (Malus sylvestris) Pumpkin (Cucurbita pepo) Quince (Cydonia oblonga)	Peduncle	Cyanol (also assimilates)		Into fruit	From observation of fruit growth and dye movement after severing peduncle xylem vessels, conclusion reached that water required by fruit could not be supplied through cortex. No protoplasmic streaming occurred in sieve tubes, but assimilates were transported without simultaneous movement of water.	1
2	Bean (Phaseolus vulgaris)	Leaf, stem	Fluorescein	2-10	B/1/	Immersion of intact leaf in 0.1% solution; subsequent movement observed with microscope.	2
3		Leaf, stem	Sodium fluorescein (uranin)		A, B	Terminal leaflet submerged in solution; substance detected in petioles of lateral leaflets after 15 hr in dark. During this period, lateral leaflets lost dry weight, suggesting simultaneous movement of dye and assimilates in opposite directions. Scalding rachises inhibited movement of dye.	3, 4
4	Bean (Phaseolus vulgaris) Cotton (Gossypium sp)	Leaf, stem, root	Sodium fluorescein (also P^{32})	7	A, B	Basipetal stem transport slower in cotton than in bean. P^{32}, applied to leaf higher than dye-treated leaf, overtook dye in movement down stem. Cotton: P^{32} moved faster than dye in petiole, and moved up from roots through phloem by a point on the stem where xylem had been removed, while dye was simultaneously moving down.	5
5	Bryony (Bryonia dioica)	Leaf, stem	Sodium fluorescein	15-65	A, B	Solution applied to small epidermal wounds of stems, petioles, and leaves of intact plants. Translocation rates in stem greatest in basal portion.	6
6	Bryony (Bryonia dioica) Elodea (Anacharis densa)	Leaf	Berberine sulfate, fluorescein, primuline, quinine chloride, rhodamine B and 6G		A, B	Relative distribution of dye between sieve tube cytoplasm and vacuole dependent on concentration and pH Microscopic examination of the proceeding dye front suggested mass flow through vacuole, possibly by electro-osmotic phenomena.	7
7	Chickweed (Stellaria media) Elodea (Anacharis densa)	Leaf	Potassium fluorescein, other acid fluorescent dyes	0-30		In elodea, movement in parenchyma cell walls slower than diffusion in gelatine and not affected by narcotics. Volume of tissue into which dye moved was independent of its concentration and loci of application. In Stellaria, different dyes moved at different rates, a humid atmosphere causing a reduction of rate. Maximum indicated rate in midvein.	8
8	Dodder (Cuscuta sp)	Leaf, stem	Fluorescein	2-50	A/2/, B/1, 2/	Substance moved basally to stem when applied to leaf veins, and then became bi-directional. Movement apparently from cell to cell through total intercellular surface and not through plasmodesmata.	9

/1/ Petiole. /2/ Stem.

Part III. HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	[B]arley (Hordeum vulgare) [B]ean (Phaseolus vulgaris) [C]ucumber (Cucumis sativus) [M]aize (Zea mays) Sunflower (Helianthus sp) Tomato (Lycopersicon esculentum)	Leaf, stem	α-Methoxyphenyl-acetic acid		A, B	Applied to stem (dicots) or leaf (monocots), compound caused epinasty or repression of terminal growth. Although phenylacetic acid produced gall at site of application in bean, it did not produce a secondary gall at internode above, as did α-methoxyphenyl-acetic acid.	6
	Barley (Hordeum vulgare) Grass, Bermuda (Cynodon dactylon) Wandering Jew (Tradescantia fluminensis, Zebrina pendula)	Leaf, stem, root	3-Amino-1,2,4-triazole; 2,4-D, 1,2-dihydro-pyridazine-3,6-dione[1]; 3-(p-chlorophenyl)-1,1-dimethyl-urea[2], 2,4,5-T, urea	0-30	A, B	Translocation determined by autoradiography at various intervals after application of C^{14}-labelled compound to 1 or several leaves, or to stolons. Movement of 2,4-D restricted due to absorption in phloem, but absorption minimized in rapidly growing plants. Other compounds translocated throughout plants to a greater extent, some moving in the phloem, others also entering xylem or moving predominantly in xylem. None moved out of chlorotic leaves.	7-9
8	Bean (Phaseolus vulgaris)	Petiole, stem, root	3-Indoleacetic acid	0.17	B	Donor, containing 3-indoleacetic acid, and receptor agar blocks applied to ends of 5 mm section. Assay of block by Avena curvature test. Infusion of 2,4-D or 2,3,5-triiodobenzoic acid into section (directly or via foliage before cutting) markedly inhibited ability to translocate 3-indoleacetic acid	10
9		Hypocotyl	3-Indoleacetic acid	0.17	B	Method of determination same as No. 8 above. Only basipetal translocation observed; maximum intensity at top of older (8 da) hypocotyls. Temp. = 24°C.	11
10		Leaf, stem	3-Indoleacetic acid, 2,4-D (morpholine salt), β-hydroxyethyl-4-chlorophenoxyacetate; p-chlorophenyl-2,4,5-trichlorophenoxyacetate; 2-bromo-3,5-dichlorobenzoic acid, (2,4-dichlorophenoxyacetyl)-urea		A, B	Substances all translocated, as detected by stem bending after application to 1 primary leaf. Sucrose, glucose, fructose, maltose, lactose, and galactose each caused 2,4-D to translocate out of pre-darkened leaf when applied simultaneously with 2,4-D.	12

/1/ Maleic hydrazide. /2/ Monuron.

Part III· HERBICIDES AND GROWTH REGULATORS

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Alligator weed (*Alternanthera philoxeroides*)	Leaf, stem	2,4-D	4.2-4.3	A, B	C^{14}-labelled 2,4-D applied to 1 pair leaves. Stems sectioned and extracted for activity determinations 8 or more hr after treatment. Acropetal movement in stem more extensive and slightly more rapid than basipetal.	1
2	Alta fescue (*Festuca arundinacea*) Barley (*Hordeum vulgare*) Grass, rye (*Lolium sp*) Oat (*Avena sp*)	Leaf	Lactic acid N-phenylcarbamate, lactic acid N-3-chlorophenylcarbamate		A, B	Application to first leaf, with measurement of subsequent repression of young leaf growth. Greater translocation of acid compounds than of corresponding isopropyl compounds, the lactic acid molecular configuration apparently being advantageous to translocation.	2
3	Apple (*Malus sp*) Pear (*Pyrus sp*)	Twig	Native auxin, 3-indoleacetic acid	0.3-0.4	B	Translocation determined in 5-10 mm sections by agar block method. Auxin in receptor block analyzed by Avena test Native auxin moved only basipetally in active twigs. Applied 3-indoleacetic acid moved in similar manner, but acropetally to a very slight extent in dormant twigs.	3
4	Apple, crab (*Malus sp*)	Stem	Native auxin	0.5-0.7	B	Stem sections placed with base on agar block. Auxin diffusing into block measured by Avena curvature test. O_2 tension, ranging from zero to that in air, gave straight line correlation with translocation rate. Within temperature range of 0-42°C, maximum transport occurred at 27-30° and was nearly zero at extremes.	4
5	Autumn-crocus (*Colchicum autumnale*) Buttercup (*Ranunculus sp*) Chickweed (*Stellaria media*) Dandelion (*Taraxacum sp*) Mustard, white (*Brassica hirta*) Orache (*Atriplex patula*) Pigweed (*Chenopodium album*)	Leaf, stem	2,4-D		A, B	Transport in orache and pigweed initially basipetal and later acropetal. Sensitivity to a second 2,4-D application was variable among different plants and depended on length of time after first application.	5

101. TRANSLOCATION OF ORGANIC SUBSTANCES: PLANTS (Continued)

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
18	Bean (Phaseolus vulgaris) (continued)	Leaf, stem, root	2,4-D		A[3], B[3,4]	Radioassay of stem and roots, after application of C^{14}-labelled 2,4-D to primary leaf, showed activity in 6 hr, with transport chiefly basipetal. After 1 wk, approximately 1/3 of C^{14} in stem still in 2,4-D, much of remainder being in an unknown water-soluble acid.	20,21
19		Leaf, stem	2,4-D			Pretreatment with gibberellic acid 48 hr before 2,4-D application increased amount of 2,4-D in untreated plant parts after several da. Gibberellic acid apparently affects translocation rather than absorption or degradation of 2,4-D.	22
20		Leaf, stem, root	2,4-D			Applied to leaves and determined in various parts by bioassay. No transport from leaves of plants kept in dark 18-24 hr prior to and during treatment. Mannitol did not facilitate movement as did sucrose. Low temperatures reduced transport.	23
21		Entire plant	2,4-D		A, B	Primary leaves severed 24 hr after application and entire remainder of plant extracted. Presence of unaltered 2,4-D determined both by bioassay of extract and by chemical characterization.	24
22		Leaf, stem	2,4-D		A, B	Application directly to apical bud caused growth repression independent of temperatures from 22-34°C. Application via primary leaf resulted in maximum repression of apical bud and leaf expansion at lower temperature	25
23		Leaf, stem	2,4-D	13-106	B	Application to primary leaf caused epicotyl curvature to appear sooner at 35°C than at 25°, but maximum angle of curvature was 60% greater at lower temperature.	26
24		Leaf, stem	2,4-D (also water)		B	The fact that labelled 2,4-D did not move rapidly downward through steam-girdled petioles (as did labelled water), along with the ability of water to move out of carbohydrate-depleted leaves (2,4-D does not), renders improbable a mass movement of 2,4-D and water in phloem.	27

/3/ Stem. /4/ Leaf.

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
11	Bean (*Phaseolus vulgaris*) (continued)	Leaf, stem, root	3-(*p*-Chlorophenyl)-1, 1-dimethylurea		A, B	1 leaf treated with C^{14}-labelled compound; plant sectioned for assay of activity 2-72 hr after treatment. Translocation throughout plant, maximum concentration in non-treated leaves occurring only by 4th da.	13
12		Leaf, stem, hypocotyl	2-Iodo-3-nitrobenzoic acid		A, B	[illegible] Accumulation in apical bud and hypocotyl indicated by radioactivity.	[illegible]
13		Leaf, stem, root	2, 4-Dichloro-5-iodophenoxyacetic acid, and 14 derivatives		B	I^{131}-labelled compounds applied to leaves, stems, and roots. Movement from leaf to stem (determined by curvature of stem) occurred only if plant kept in light. As spray, I^{131}-labelled 2, 4-D-5-iodophenoxyacetic acid less [illegible]	15
14		Leaf, stem, root	2, 4-Dichloro-5-iodophenoxyacetic acid (*free acid and* morpholine salt)		A, B	[illegible] to 1 primary leaf. Concentration in stem significantly greater with acid than with morpholine salt, and markedly increased by addition of wetting agent.	[illegible]
15		Leaf, stem	Various butyl, octyl, and octadecyl esters of 2, 4-D and 2, 4, 5-T		B	Application to 1 primary leaf, with resultant stem curvature measured after 4 hr. Only plants kept in light developed curvature Temp. = 21-24°C.	17
16		Leaf, stem, root	2, 4-D		A, B	Methylene C^{14}-labelled 2, 4-D applied to midrib of 1 primary leaf. Plants sectioned 2-144 hr after application and activity determined Activity in apical bud after 8 hr, but no movement into leaf opposite treated leaf.	18
17		Leaf, stem	2, 4-D		A[3], B[4]	Content of 2, 4-D in various plant parts determined by bioassay after application to primary leaf Entered epicotyl in 6 hr, but did not move below center of hypocotyl. Transport inhibited in case of 2nd application or too high a concentration, due to phloem destruction. Sucrose, but not mannitol and urea, enhanced transport in dark.	19

/3/ Stem. /4/ Leaf.

Part III. HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
18	Bean (Phaseolus vulgaris) (continued)	Leaf, stem, root	2,4-D		A[3], B[3,4]	Radioassay of stem and roots, after application of C^{14}-labelled 2,4-D to primary leaf, showed activity in 6 hr, with transport chiefly basipetal. After 1 wk, approximately 1/3 of C^{14} in stem still in 2,4-D, much of remainder being in an unknown water-soluble acid.	20,21
19		Leaf, stem	2,4-D			Pretreatment with gibberellic acid 48 hr before 2,4-D application increased amount of 2,4-D in untreated plant parts after several da. Gibberellic acid apparently affects translocation rather than absorption or degradation of 2,4-D.	22
20		Leaf, stem, root	2,4-D			Applied to leaves and determined in various parts by bioassay. No transport from leaves of plants kept in dark 18-24 hr prior to and during treatment. Mannitol did not facilitate movement as did sucrose. Low temperatures reduced transport.	23
21		Entire plant	2,4-D		A, B	Primary leaves severed 24 hr after application and entire remainder of plant extracted. Presence of unaltered 2,4-D determined both by bioassay of extract and by chemical characterization.	24
22		Leaf, stem	2,4-D		A, B	Application directly to apical bud caused growth repression independent of temperatures from 22-34°C. Application via primary leaf resulted in maximum repression of apical bud and leaf expansion at lower temperature.	25
23		Leaf, stem	2,4-D	13-106	B	Application to primary leaf caused epicotyl curvature to appear sooner at 35°C than at 25°, but maximum angle of curvature was 60% greater at lower temperature.	26
24		Leaf, stem	2,4-D (also water)		B	The fact that labelled 2,4-D did not move rapidly downward through steam-girdled petioles (as did labelled water), along with the ability of water to move out of carbohydrate-depleted leaves (2,4-D does not), renders improbable a mass movement of 2,4-D and water in phloem.	27

/3/ Stem. /4/ Leaf.

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
25	Bean (Phaseolus vulgaris) (continued)	Leaf, stem, root	2, 4-D and derivatives	4	A, B	Translocation determined by autoradiogram, stem curvature, and apical leaf growth repression after application to 1 primary leaf. Kerosene served as good carrier in destarched plants, and appeared to move through intercellular spaces of phloem parenchyma.	28
26		Leaf, stem	2, 4-D; 2, 4-D complex		B	C^{14}-labelled 2, 4-D applied to veins of 1 leaf of etiolated plants; activity determined in sections made 4 da later. Addition of glucose or sucrose to 2, 4-D increased movement; addition of glucose-1-phosphate did not. Temp. = 16-24°C.	29
27		Leaf, stem	2, 4-D (ammonium salt)		A, B	Primary leaf excised 4-72 hr after application, and fresh weight of apical leaves determined after 9 da. Increased translocation rate from leaf at high light intensities.	30
28		Leaf, stem	2, 4-D (ammonium salt); 2, 4, 5-T; α-napthaleneacetic acid		B	Movement from primary leaf to stem determined by C^{14} activity in stem (using C^{14}-labelled 2, 4-D), or by stem curvature. Boron applied to tip of treated leaf failed to affect translocation, as did sugar. Boron added to sugar markedly increased translocation of growth substances.	31
29		Leaf, stem, root	2, 4-D (sodium salt); 2, 4, 5-T (sodium salt)	50-100	B	Applied to 1 primary leaf in a carrier of pH 8, 4 hr required for epicotyl to bend. 2 hr required at pH 2.	32
30		Leaf, stem, root	2, 4-D, 3-indoleacetic acid		A[3], B[3, 4]	Activity determined in various plant parts after application of C^{14}-labelled 3-indoleacetic acid to primary leaf. 10-14% of activity transported out of treated leaf in 14 da, but activity in petiole and lower stem reached maximum after 1 da. Terminal bud reached maximum after 7 da. 2, 4-D moved out of treated leaf more rapidly.	33
31		Leaf, stem, root	Benzoic acid, 2, 4-D (triethanolamine salts)		B	Transport, determined by autoradiography and counting, was maximum at high temperature (30° over 20°C) and high humidity (72% over 36%). Maximum effect at high humidity correlated with large stomatal openings.	34

/3/ Stem. /4/ Leaf.

117. TRANSLOCATION OF ORGANIC SUBSTANCES PLANTS (Continued)

Part III. HERBICIDES AND GROWTH REGULATORS (Continued)

Plant	Part	Substance	Translocation		Remarks	Reference
			Rate cm/hr	Direction		
(A)	(B)	(C)	(D)	(E)	(F)	(G)
Bean (Phaseolus vulgaris) (continued)	Hypocotyl	3-Indoleacetic acid		B	Transport in sections, determined by bioassay of receptor blocks, was inhibited by 2,4-D; 2,4-dichlorophenoxypropionic acid; 2,4,6-trichlorophenoxyacetic acid, 3-indolepropionic acid, and 2,3,5-triiodobenzoic acid. Other compounds did not inhibit transport.	35
	Leaf, stem, root	a-Methoxyphenylacetic acid		B	Radioassay of nutrient culture solution, after application of C^{14}-labelled compound to primary leaves, showed translocation through roots into nutrient, reaching maximum after 126 hr. Decreased nutrient aeration, or severing part of roots, decreased exudation into nutrient, but exudation later increased after severed roots renewed growth.	36
	Leaf, stem, root	2,3,6-Trichlorobenzoic acid, 2,3,5,6-trichlorobenzoic acid		A, B	Application to first internode, cotyledon, or primary leaf, resulted in movement to root, through soil, and into adjacent plants, as determined by growth modification. Transport from leaf to stem took 4 hr. Other chlorinated benzoic acids did not affect adjacent plants.	37
	Stem	Gibberellic acid			C^{14}-labelled compound applied to first internodes of young plants; translocation determined by autoradiography after 24-48 hr.	38
	Leaf, stem	Gibberellic acid		A	Application by foliage spray or to stem base or apex caused an increase in stem length of 0-300% in various plant species, indicating translocation.	39
	Leaf, stem	2,4-Dichlorobenzylnicotinium chloride; 3,4-dichlorobenzylnicotinium chloride; p-chlorobenzylnicotinium chloride, other nicotinium compounds		A[3], B[4]	Translocation, indicated by per cent reduction in stem elongation 10 da following treatment of specific parts, as follows: first internode, 34%, hypocotyl, 23%, leaves, 7%; cotyledon, no reduction. 2,4-compound most effective, and young plants most sensitive.	40

/3/ Stem. /4/ Leaf.

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
38	Bean (Phaseolus vulgaris) (concluded)	Leaf, stem, root	3-Amino-1,2,4-triazole		A[3,4], B[3,4]	C^{14}-labelled compound applied to primary leaves moved basipetally in stem during first 24 hr, but radiochromatography of plant sections after 5 da showed C^{14} concentrated in terminal bud and aminotriazole converted to 2 unknowns. Only 7% of total activity remained as aminotriazole by 5th da, and about half of activity had moved out of treated leaves.	41
39	Bean (Phaseolus vulgaris) Cotton (Gossypium sp) Cucumber (Cucumis sativus) Morning-glory (Ipomoea sp) Pea, black-eyed (Vigna sinensis)	Leaf, stem, root	2,4-D (acid, amine, ester, and sodium salt formulations)	0-70	A, B	Transport determined by autoradiography at intervals of 15 min-144 hr after application to specific cotyledons or leaves. 2,4-D reached bean roots in 3 hr and terminal bud in 6 hr, and moved out of cotyledons or basal leaves more rapidly than out of young leaves. It is transported with assimilates, and may move in water-stressed plants. Effect enhanced by low pH and surfactants.	42,43
40	Bean (Phaseolus vulgaris) Cotton (Gossypium sp) Maize (Zea mays) Millet (Pennisetum sp) Rice (Oryza sativa) Soybean (Glycine max)	Leaf, stem, root	2,4-D; other halogenated phenoxyacetic acids		A, B	Application of labelled compound to 1 leaf and harvest of plant at intervals for C^{14} assay demonstrated that translocation, but not penetration or metabolic inactivation, was correlated with varietal susceptibility. Translocation of phenoxy acids in several dicots was 5-70 times greater than in monocots, in the following decreasing order: 4-fluoro-; 2,4-difluoro-; 4-chloro-, 2,4-dichloro-, 2,4,5-trichloro-.	44
41	Bean (Phaseolus vulgaris) Cotton (Gossypium sp) Soybean (Glycine max) Tomato (Lycopersicon esculentum)	Leaf, stem	2,4-D (ammonium salt)		A, B	Growth reduction as affected by application to individual leaves of various ages. Maximum reduction achieved with application to apical leaves or stem. No basipetal movement occurred through dead stem segments.	45
42	Bean (Phaseolus vulgaris) Maize (Zea mays)	Leaf, stem	Fungal metabolites		A[3], B[4]	Application of filtrate of Penicillium thomii or Arachniotus trisporus culture to 1 leaf resulted in growth repression and abnormal development of subsequent leaves.	46

/3/ Stem. /4/ Leaf.

117. TRANSLOCATION OF ORGANIC SUBSTANCES: PLANTS (Continued)

Part III HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
43	Bean (Phaseolus vulgaris) Maize (Zea mays) Oat (Avena sp)	Leaf, stem	2-Iodo-3-nitrobenzoic acid		A[3,4], B[4]	Activity of I^{131} determined in young leaves 8 da after application of labelled compound to old leaves. Accumulation greatest in bean, with activity concentrated in meristematic regions.	47
44	Bean (Phaseolus vulgaris) Maize (Zea mays) Sunflower (Helianthus sp)	Leaf, stem, root	2,4-Dichloro-5-iodophenoxyacetic acid (morpholine salt)		A, B	Determination of activity in various plant parts and time intervals after application of I^{131}-labelled compound to 1 leaf. Activity in bean hypocotyl appeared 6 hr after application. Movement slower from maize, oat, and wheat leaves.	48
45	Bean (Phaseolus vulgaris) Oat (Avena sp)	Leaf, stem, root	2-Iodo-4-chlorophenoxyacetic acid	1.9-3.8[5]	A, B	I^{131}-labelled material applied to 1 leaf; followed at various intervals by autoradiogram. Bean: movement throughout plant in 27 hr.	49
46	Bean (Phaseolus vulgaris) Sugar cane (Saccharum officinarum)	Leaf, stem	2,4-D		A[3], B[3,6]	C^{14}-labelled 2,4-D applied to a lower leaf (activity determined by subsequent formative effect and radioassay) was readily absorbed by both bean and sugar cane. However, about 10 times more C^{14} was translocated to the growing point of the bean than to the cane.	50
47	Bean, broad (Vicia faba) Maize (Zea mays)	Root	3-Indoleacetic acid, native auxin		A, B	Polarity of movement of externally applied or native auxin in root sections determined by bioassay of receptor agar block. Movement within 1-2 mm of tip was predominantly downward, but within zone 2-4 mm from tip movement was largely upward.	51-53
48	Bean, Florida velvet (Stizolobium deeringianum)	Leaf, stem	3-(p-Chlorophenyl)-1,1-dimethylurea		A	Short midstem section (intact plants) immersed in solution of substance several da. Only leaves acropetal to treated section showed typical injury after 6 da.	54
49	Chilicothe (Echinocystis macrocarpa) Maize (Zea mays)	Stem	Gibberellic acid	0.5-1.0		Bioassay with mutant dwarf maize demonstrated longitudinal movement in internode sections to be double the rate of lateral movement.	55
50	Cocklebur (Xanthium sp) Maize (Zea mays) Peanut (Arachis hypogaea) Tomato (Lycopersicon esculentum)	Leaf, stem, root	1,2-Dihydropyridazine-3,6-dione[1]		A[3], B[3,6]	Repeated application to single leaf or by spraying resulted in translocation of substance to regions of meristematic activity, as indicated by formative effect.	56

/1/ Maleic hydrazide. /3/ Stem. /4/ Leaf. /5/ For bean; rate slower in oat. /6/ Petiole.

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
51	Coleus (*Coleus blumei*)	Stem, root	Native auxin, 3-indoleacetic acid	0.2	A[7,8], B[3,8]	Donor, containing 3-indoleacetic acid, and receptor agar blocks placed on ends of sections; activity determined by pea root test. Acropetal movement of native auxin in intact plants shown by darkening stems; only flowering stems responded phototropically after treatment.	57
52		Stem	3-Indoleacetic acid		A, B	Transport in section from 2nd internode from apex determined by donor-receptor block technique, using Avena bioassay. Basipetal movement 3 times that of acropetal movement.	58
53	Cotton (*Gossypium sp*)	Leaf, stem	3-Amino-1,2,4-triazole		A, B	Apical or basal leaves submerged in solution. Injury appearing in non-treated leaves indicated bi-directional movement in stem, but only acropetal movement could traverse stem girdle.	59
54		Cotyledon, stem, root	3-Amino-1,2,4-triazole; 2,4-D, urea		B	Radioanalysis of culture solution a few days after application of C^{14}-labelled compounds to cotyledons showed only 2,4-D exuded from roots, although all compounds were translocated to roots in 2 hr. Because of absorption in tissue, distribution of 2,4-D in plants was less than with other compounds.	60
55	Cotton (*Gossypium sp*) Flax (*Linum sp*) Milo (*Sorghum vulgare*) Rice (*Oryza sativa*) Watermelon (*Citrullus vulgaris*)	Cotyledon, leaf, stem	1,2-Dihydropyridazine-3,6-dione[1]		A, B	Application as a spray, or only to cotyledons and stem, resulted in translocation to meristematic regions, as evidenced by stunting and development of abnormal leaves.	61
56	Cucumber (*Cucumis sativus*)	Cotyledon, hypocotyl	3-Indoleacetic acid	18.5 (15.1-21.9)[9]		Difference in time for hypocotyl curvature to appear at 20°C, when substance is applied to cotyledon tip rather than in direct hypocotyl application, indicates translocation rate in cotyledon.	62
57	Grass, canary (*Phalaris canariensis*)	Coleoptile	Native auxin		B	Phototropic response below tip of seedling receiving unilateral illumination. Curvature resulted from exposing seedlings to lateral light.	63

/1/ Maleic hydrazide. /3/ Stem. /7/ Root tip. /8/ Flowering stem. /9/ Estimate "b" (cf. Introduction).

117. TRANSLOCATION OF ORGANIC SUBSTANCES. PLANTS (Continued)

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
58	Grass, Johnson (Sorghum halepense) Grass, nut (Cyperus rotundus)	Leaf, stem, rhizome	3-Amino-1,2,4-triazole	0.03-0.05	Horizontal through rhizomes A, B	30 da after foliage spray, rhizomes were separated and planted. Shoots arising were stunted and chlorotic. Translocation increased by addition of wetting agents.	64
59	Grass, nut (Cyperus rotundus)	Leaf, stem, root, tuber	3-Amino-1,2,4-triazole, 2,4-D, 2,4,5-T, 1,2-dihydropyridazine-3,6-dione[1]	20-25	A[3,4], B[3,4]	Transport determined by autoradiography after application to single leaf. 3-Amino-1,2,4-triazole reached root tip in 2 hr; 2,4-D and 2,4,5-T were slower. No movement out of treated leaf if kept in dark.	65
60	Hickory (Carya tomentosa) Privet (Ligustrum vulgare)	Leaf, stem	Ammonium sulfamate	0.6-2.5	A, B	S^{35}-labelled material applied to stem frill, followed by autoradiogram. Acropetal movement traversed stem girdle, but basipetal movement did not.	66
61	Lemon (Citrus limon)	Stem	3-Indoleacetic acid		B	Substance applied to upper edge or cut surface of cutting increased root formation near base. Basipetal movement inhibited by cooling portion of cutting at 1-8°C, and also by girdling.	67
62	Maize (Zea mays)	Root	Native auxin		A	Excised root sections were inhibited in growth and regained geotropic response only when root tips were placed on apical end and not when placed on morphological upper end	68
63	Maize (Zea mays) Oat (Avena sativa)	Leaf, stem, root	Isopropyl N-phenylcarbamate		A, B	C^{14}-labelled compound applied to cut surface of oat leaf, translocation of approximately 1% or less to stem or root within 7 da. Absorption and movement from cut or intact root even smaller. No transport in maize.	69
64	Maize (Zea mays) Oat (Avena sativa) Papaya (Carica papaya)	Coleoptile, stem	3-Indoleacetic acid, indolebutyric acid, anthraceneacetic acid, naphthaleneacetic acid	0.2-1.2	B	Sections interposed between donor agar block and 1 side of cut surface of decapitated *Avena* coleoptile. Increased time for curvature to appear indicated time for transport through section. All substances used for oat, only 3-indoleacetic acid for maize and papaya.	70
65	Maize (Zea mays) Pea (Pisum sativum)	Leaf, stem, root	Trichloroacetic acid (sodium salt)		A, B	Outer half of 3rd leaf dipped into solution of C^{14}-labelled substance. After 24 hr, measurements and autoradiograms indicated movement into roots and other leaves. No apparent metabolism to other products.	71

/1/ Maleic hydrazide /3/ Stem. /4/ Leaf

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
66	Maize (Zea mays) Wheat (Triticum sp)	Leaf, stem, root	2,4-D		A, B	2,4-D and 3 of its metabolic products recovered throughout plants 1-4 da after application of C^{14}-labelled 2,4-D to older leaf. Determinations by radiochromatography. Most activity occurred in young leaves, some in stem and sheath, and least in roots.	72
67	Marabu (Dichrostachys nutans)	Shoot	2,4,5-T (butoxyethanol ester)		A	Substance, applied in oil or water at different levels on surface of shoot, was translocated acropetally, as evidenced by bioassay of tissues and ultimate death of leaves and stems above treated area. Slight basipetal movement occurred with bark application, as indicated by inhibition of basal sprouting.	73
68		Stem	2,4-D (butoxyethanol ester)		A, B	Positive recovery (determined by bioassay) 19 cm from top of 2-ft sucker, 6 hr after apical application. No recovery after 30 hr suggests rapid transport and/or metabolism. Transport also shown by effect on basal buds which were inhibited in sprouting even when shoot was excised 6 hr after application. Acropetal transport occurred through stem girdle; basipetal did not, and was therefore extra-axillary.	74
69	Mesquite (Prosopis juliflora)	Leaf	2,4,5-T (various formulations)		A/3/, B/3,4/	Maximum translocation out of branch tips 50-90 da after leaf emergence in spring, when root sugars undergo rapid buildup. Little translocation if total root sugars are decreasing and reducing sugars are abundant. Anatomical studies showed phloem proliferation, and resultant transport inhibition could occur from too high concentration of either 2,4,5-T or surfactant.	75,76
70		Leaf, stem, root	2,4-Dichloro-5-iodophenoxyacetic acid		B	Activity determined in more basal tissue 4 da after spraying upper half of plant with solution of I^{131}-labelled compound. Use of emulsifying agent increased proportion of activity in root and hypocotyl over that in stem, but less than 3% moved from treated foliage.	77

/3/ Stem. /4/ Leaf.

Part III HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
71	Mesquite (Prosopis juliflora) (concluded)	Leaf, stem	2,5-D (butoxyethoxypropanol ester), 3,4-D (butoxyethanol ester), 2,2-dichloropropionic acid		A, B	Apical epinasty and injury to young leaves, also injury to basal leaves determined at intervals after application to central leaves. Acropetal movement far more intense than basipetal.	78
72	Oak (Quercus douglasii, Q wislizenii) Ceanothus (Ceanothus cuneatus) Coyote brush (Baccharis pilularis) Manzanita (Arctostaphylos manzanita) Toyon (Photinia arbutifolia) Willow (Salix lasiolepis)	Leaf, stem	2,4-D, urea		A[3], B[3,4]	Autoradiography of bark samples collected 1-21 da after treatment of single leaf with C^{14}-labelled compound, at distances up to 150 cm from leaf. Acropetal transport less pronounced than basipetal, and dependent on plant species and season. Transport active many months in evergreen species, but only for short period in deciduous. Contact injury inhibited, and soil mixture enhanced, translocation.	79
73	Oat (Avena sativa)	Coleoptile	3-Indoleacetic acid		Lateral	After 1 hr of symmetrical application to cut surface, direct electrical current was applied across coleoptile for 2 min. Subsequent curvature indicated lateral transport.	80
74		Coleoptile	3-Indoleacetic acid	0.8-1.5	B	Donor agar blocks, containing 3-indoleacetic acid, and receptor blocks applied to ends of 2 mm sections; amount translocated determined by bioassay. Velocity of transport not wholly independent of temperature. Quantity increased from 0-40°C.	81
75		Coleoptile	3-Indoleacetic acid	0.4-0.8	B	Basal translocation, as determined by donor-receptor block method in 5 mm sections, inhibited by potassium cyanide and dinitrophenol.	82
76		Coleoptile	3-Indoleacetic acid		B	By using donor blocks (containing C^{14}-labelled 3-indoleacetic acid), and analyzing receptor blocks (radio- and bioassay) after 1-3 hr transport through sections, it was shown that donor activity increased as original donor concentration increased up to 1.6 mg/L, whereas receptor activity reached maximum at a lower original donor concentration. Such activity indicates saturation of transport capacity at low concentrations.	83

/3/ Stem. /4/ Leaf.

Part III. HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
77	Oat (Avena sativa) (concluded)	Coleoptile	Native auxin	1.0-1.5	B	Calculation of transport rate based on various phototropic and geotropic responses, plus curvatures induced by applied auxin.	84
78	Pea (Pisum sativum)	Stem	Gibberellic acid	0.2	A, B	Donor-receptor block technique, utilizing 5-mm etiolated internode sections in conjunction with both photometric- and bioassay. No polarity. Acropetal and basipetal transport approximately equal.	85
79		Epicotyl	Gibberellic acid	60-600	A	Application of gibberellic acid to basal end of 100-mm etiolated section, subsequently followed by 3-indoleacetic acid application to a 5-mm section excised from apical end. Growth of section greater than that of controls receiving no gibberellic acid. Data resulting from adjustment of original section length and time interval before excision of apical section suggest rapid gibberellic acid transport and synergistic effect with 3-indoleacetic acid.	86
80	Pea (Pisum sativum) Tomato (Lycopersicon esculentum)	Leaf, stem, root	2, 4-D		A[3], B[3, 4]	Basipetal movement more extensive than acropetal, as determined by radioassay at various intervals after application of C^{14}-labelled compound to lower leaf. Of 2 active metabolic products of 2, 4-D, 1 was more common in pea and the other in tomato.	87
81	Peanut (Arachis hypogaea)	Gynophore	3-Indoleacetic acid	0.9	B	Short sections (3-5 mm) excised from gynophore just beneath ovule. Translocation determined by donor-receptor agar block method at 25°C, activity in blocks being determined by Avena test.	88
82	Potato (Solanum tuberosum)	Leaf, stem, root, tuber	Gibberellic acid		B	Foliar application 4, 2 or 1 wk before harvest of tubers resulted in their premature sprouting, thus suggesting rapid translocation in plants.	89
83	Soybean (Glycine max)	Leaf, stem, root	2, 4-D (sodium salt); also P^{32}			Transport (determined by growth repression after severing basal leaf at various intervals following application of substance) was reduced by low leaf carbohydrate content. Temperature coefficient for transport of 2, 4-D and P^{32} (determined by autoradiography) showed Q_{10} values of approximately 2.	90

/3/ Stem. /4/ Leaf.

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
84	Spider flower, giant (Cleome spinosa)	Stem	2,4-D; 3-indoleacetic acid; naphthaleneacetic acid		A, B	Application to stem in form of ring. Translocation determined by degree of rooting of cuttings taken above or below application point. Transport in both directions across stem girdle indicated principal movement in xylem.	91
85	Squash (Cucurbita maxima) Tomato (Lycopersicon esculentum)	Stem	Native auxin, 3-indoleacetic acid	20	B	Squash: analysis (*Avena* test) of 3-indoleacetic acid content above and below girdled stem sections at specific distances from point of application. Tomato, both substances moved only basipetally in stem sections, as determined by agar block technique. Temp. = 24-26°C.	92
86	Strawberry (Fragaria sp)	Leaf, runner	1,2-Dihydropyridazine-3,6-dione[1] (diethanolamine salt)		B[4]	Activity detected by autoradiography in runner tips 30 hr after application of C^{14}-labelled compound to mature leaf. Substance could move through several crowns to concentrate in a runner tip, but did not move against growth gradient back toward formed crown of plant.	93
87	Sugar cane (Saccharum officinarum)	Leaf, stalk, root	2,4-D		A, B	Radioassay, after application of C^{14}-labelled 2,4-D to single leaf, showed very little translocation to growing tips of shoot and root and to young leaves, as compared to translocation in bean.	94
88	Sunflower (Helianthus sp)	Hypocotyl	3-Indoleacetic acid		B	Donor-receptor agar block technique demonstrated only basipetal transport in hypocotyl sections. Inhibition of chlorinated phenoxyacetic acids, upon polar transport of 3-indoleacetic acid (IAA), studied by applying IAA at apical end and inhibitor at basal end IAA content in receptor block determined by *Avena* test. Increased inhibition correlated with increased chlorination of phenoxyacetic acids.	95,96
89	Sunflower (Helianthus sp) Tobacco (Nicotiana tabacum)	Stem	3-Indoleacetic acid		B	Transport measured in sunflower epicotyl sections by donor-receptor block technique, after infusion of various substances. Polar movement inhibited by respiratory inhibitors (e g., KCN) and SH-inactivating compounds (e.g., iodoacetate). Tobacco sections, cultured in nutrient with triiodobenzoic acid, contained equal distribution of 3-indoleacetic acid (IAA), whereas controls accumulated IAA in basal end, thus indicating nullification of polarity.	97,98

/1/ Maleic hydrazide. /4/ Leaf.

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
90	Sweet potato (*Ipomoea batatas*)	Leaf, petiole	3-Indoleacetic acid		B	Application of 3-indoleacetic acid to lamina; transport determined by anomalous phototropic and geotropic response of petiole. Triiodobenzoic acid, placed between application point and responsive area, negated response, indicating inhibition of transport.	99
91	Thistle, Canada (*Cirsium arvense*) Grass, Johnson (*Sorghum halepense*) Soybean (*Glycine max*)	Leaf, stem, root	3-Amino-1, 2, 4-triazole		A, B	Autoradiography and chromatography of plant parts after application of C^{14}-labelled compound to leaf, or leaf axil, showed movement throughout plant in 30 hr. Metabolism rate of 3-amino-1, 2, 4-triazole variable in different species, as determined by appearance of a labelled unknown.	100
92	Tobacco (*Nicotiana* sp)	Stem	1, 2-Dihydropyridazine-3, 6-dione[1]		B	Application to cut surface after topping resulted in basipetal transport, as determined by inhibition of adventitious buds and increased formation of carbohydrates in leaves developing subsequent to treatment.	101
93		Stem	3-Indoleacetic acid, native auxin		B	2, 6-Dichlorobenzoic acid and 2, 5-dibromobenzoic acid (and related compounds) inhibited polar auxin transport, as determined by distribution of callus on stem segments, pith cell enlargement, and by distribution of C^{14}-labelled 3-indoleacetic acid.	102
94	Tomato (*Lycopersicon esculentum*)	Leaf	3-(*p*-Chlorophenyl)-1, 1-dimethylurea		A[10], B[11]	Application of C^{14}-ring-labelled compound to terminal leaflet; subsequent movement followed by autoradiogram. Very little basipetal movement in leaves. Acropetal movement only when compound given via root system.	103
95		Leaf, stem, root	3-Indoleacetic acid, indolebutyric acid, naphthaleneacetic acid, phenylacetic acid, phenylpropionic acid		A[10], B[11]	Application of substance in lanolin to lower stem. Epinasty of stem and leaves developed more slowly in older tissue.	104
96		Leaf, stem, root	2, 4-D		A[3], B[3, 4]	C^{14}-labelled 2, 4-D applied to first true leaf of P-deficient plants. Translocation from leaf determined by stem curvature and autoradiography. Addition of P to nutrient 8 hr or 3 da before application increased translocation, particularly with 3-da pretreatment.	105

/1/ Maleic hydrazide. /3/ Stem. /4/ Leaf. /10/ Movement principally in xylem. /11/ Slight movement.

Part III: HERBICIDES AND GROWTH REGULATORS (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
97	Tomato (Lycopersicon esculentum) (concluded)	Leaf, stem, root	2,4-D		B	K-deficient plants given K via roots 3 da before, or simultaneously with, 2,4-D application to 1 leaflet showed greater transport than plants given K 24 hr after 2,4-D, as evidenced by growth repression, formative effect, and autoradiography.	106
98		Leaf, stem, root	2,4-D (sodium salt)		A, B	Movement throughout plant determined by photometric chemical analysis 24-48 hr after application to 2nd basal leaf or to soil.	107
99		Leaf, stem, root	Gibberellic acid		A, B	Application to soil, individual leaves, stem apices, or flower peduncles, caused increase in parthenocarpic fruit set, suggesting translocation in either phloem or xylem.	108

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117. TRANSLOCATION OF ORGANIC SUBSTANCES PLANTS (Continued)

Part IV: VIRUSES

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Bean (Phaseolus vulgaris)	Leaf, stem	Virus causing southern bean mosaic			Virus moved from inoculated leaf down stem, across approach graft, and up stem of 2nd plant through a steamed section (as evidenced by necrotic areas above steamed region), thus suggesting movement in tracheal elements.	1
2	Bean (Phaseolus vulgaris) Tobacco (Nicotiana tabacum)	Leaf, stem	Virus causing tobacco mosaic, tobacco ring spot, cucumber mosaic; potato virus X		A, B	Virus moved distally out of darkened (starch free), inoculated leaves as sugars moved in (indicated by accumulation of starch in such leaves, and by recovery of virus and inoculation to appropriate indicator plants).	2
3	Beet, sugar (Beta vulgaris)	Leaf	Virus causing sugar beet curlytop	9-36	B	1 leaf inoculated by leafhopper (Cerculifer tenellus), plant infectivity determined by excising petiole base at various intervals after inoculation Temp. = 34-40°C.	3
4		Leaf	Virus causing Argentine curlytop	1 5	B	Infectivity of plant determined after viruliferous leafhoppers (Agalliana ensigera) had fed 2 hr on leaf tip, leaf severed 15 cm below point of feeding. Temp. = 38°C.	4
5	Beet, sugar (Beta vulgaris) Tobacco (Nicotiana tabacum)	Leaf, cotyledon, stem	Virus causing sugar beet curlytop	Beet leaf: 25-152 Beet cotyledon: 30 at 16°C, 51 at 29°C, 76 at 43°C, 76 at 57°C Tobacco 1.3	B	Tobacco. Viruliferous leafhoppers (Cerculifer tenellus) allowed to feed on youngest leaves. Stem later segmented, and segments rooted and observed for disease. No movement from apex during first 24 hr after feeding Sugar beet. Leafhoppers allowed to feed on leaf or cotyledon tips, these organs then severed at specific times and measured at intervals below point of feeding	5
6	Dodder (Cuscuta subinclusa)	Stem	Virus causing cucumber mosaic	0.2-10.2	A	When dodder stem was connected in line to 3 tobacco plants, only center plant infected; movement of virus almost entirely to healthy plant at apical end of dodder. More rapid movement shown by leafhopper feeding experiments.	6
7	Globe amaranth (Gomphrena globosa) Potato (Solanum tuberosum) Tobacco (Nicotiana tabacum)	Leaf, stem	Potato viruses X and Y	0.2-0.7[1] 0.004-0.012[2]		Application over leaf veins resulted in more rapid movement along a 6-mm path than with application over intercostal areas. In stem, Y virus moved faster than X, possibly due to inactivation of X virus in phloem.	7
8	Maize (Zea mays)	Leaf	Virus causing maize streak	20	B	Inoculation at distal end of 1 leaf with viruliferous leafhopper (Cicadulina mbila), after which leaf was severed at known distance and plant retained for observation of infectivity. Temp = 30°C.	8

/1/ Stem /2/ Leaf

117. TRANSLOCATION OF ORGANIC SUBSTANCES: PLANTS (Continued)

Part IV: VIRUSES (Continued)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
9	Peach (*Prunus persica*)	Stem	Virus causing yellow-red or X disease of peach		A	Translocation of virus, from diseased bud placed on stem to apical portion of plant, could be increased by darkening upper half of plant for 2 wk, as shown by symptomatic appearance.	9
10	Potato (*Solanum tuberosum*)	Leaf, stem, rhizome, [illegible]	Virus causing *leaf roll*		B	Per cent of infected tubers at various intervals after inoculation of leaf: 6 da, 0%; 10 da, [illegible]	10
11	[illegible] obconica)	[illegible]	[illegible] necrosis		[illegible]	[illegible] did not cause full systemic infection as in certain other plants (only isolated islets of infected tissue appeared). In some cases presence could be detected only by transmission and serological tests. Temp. = 16-27°C.	[illegible]
12	Raspberry (*Rubus sp*)	Cane	Virus causing *raspberry* leaf curl		A, B	An inoculated cane did not *rapidly transmit virus to other* canes on same plant unless canes were cut back. Assimilates essential for regrowth (secured from the infected cane) during *their movement transported* virus to new canes or suckers.	12
13	Tobacco (Nicotiana tabacum)	Normal callus tissue	Virus causing tobacco mosaic	0.0005		Transport rate determined by inoculating 1 end of strips cut from tissue cultures of normal callus. At intervals up to 32 da, strips cut into 4 pieces and each piece sub-cultured and tested for infectivity on Nicotiana glutinosa leaves.	13
14		Leaf, stem, root	Virus causing tobacco mosaic	0.02[3] 0.04[4] 0.85[5]		Virus inoculated into leaf moved at rates shown, and finally much faster in stem phloem, as determined by cytological abnormalities. Virus may be transported not as complete entity, but as smaller, *non-infective, precursory* particles which are not capable of combining in sieve elements, but only in adjacent parenchyma.	14
15	Tobacco (Nicotiana sylvestris)	Leaf	Virus causing tobacco mosaic	0.0007-0.0009		Inoculation to upper leaf surface resulted in movement to lower surface in 36-40 hr at rate shown.	15
16	Tobacco (Nicotiana sp)	Leaf	Virus causing tobacco mosaic	0.1-0.3	B	Leaf severed at specific distance and time after inoculation of *virus, plant observed* for development of disease symptoms.	16
17	Tomato (Lycopersicon esculentum)	Leaf, stem, root	Virus causing tobacco mosaic	0.2-0.5	A, B	*Tobacco: Inoculum applied to single* basal quarter of central leaf. Movement to apical leaves occurred in 3 da, and to roots in 5 da. Spread of virus to other quarters of inoculated leaf took 2-3 wk at 24°C. Tomato: Movement to extreme ends of plant occurred 6 da after inoculation of central leaf. Sectioning of stem, and subsequent germination of cuttings, indicated lack of virus concentration in any specific stem area.	17

/1/ Stem. /2/ Leaf. /3/ Intercostal epidermis. /4/ Elongated epidermal cells along veins. /5/ Elongated bundle sheath cells.

Part IV: VIRUSES (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
18	Tobacco (Nicotiana sp) Tomato (Lycopersicon esculentum) (concluded)	Leaf, stem, root	Virus causing tobacco mosaic, cucumber mosaic, tobacco streak, severe etch (tobacco), tobacco mosaic, cucumber mosaic, potato ring spot (tomato)	0.4	A, B	Application of inoculum to surface of central portion of root resulted essentially in movement toward root tip, as determined by later maceration of tissue and inoculation to similar host. Inoculation at stem base resulted, however, in movement to both aerial plant parts and roots.	18
19		Leaf, stem	Virus causing tomato aucuba mosaic, tobacco mosaic (tomato, tobacco)	0.3	A, B	Virus inoculated on either apical or basal leaf did not pass to opposite end of plant if central internode had been steamed, suggesting movement in phloem. Tomato plants, inoculated on 1 leaf near center of stem, were cut into sections after 3 da and planted as cuttings. All cuttings germinated, but those apical to inoculated leaf showed greatest infectivity.	19
20	Tomato (Lycopersicon esculentum)	Stem	Virus causing tomato mosaic	0.1-0.2	A, B	Plants, having lateral branches layered and rooted in separate pots, were inoculated at apex of main stem. Secondary plants severed from inoculated parent plant after 3-19 da and observed for development of disease. Half of plants received virus if allowed to remain attached to parent 10 da.	20
21		Leaf, stem, root	Virus causing tomato mosaic	18	A, B	44 hr was minimum time for movement of virus from inoculated leaf throughout stem. Upon reaching stem, virus generally translocated bi-directionally, but occasionally moved only up or down. Presence was determined by inoculating tissue extracts on tobacco test plants.	21
22		Leaf, stem, root	Virus causing tobacco mosaic	1-4	A, B	Virus moved out of central inoculated leaf after 3 da, then to root in less than 12 hr, and finally rapidly to top. Virus moved to fruit 1-2 da after leaving inoculated leaf. Translocation determined by sectioning stem at various intervals, extracting sections, and inoculating test plant with extract.	22
23		Leaf, stem	Potato virus X; virus causing tomato aucuba mosaic, tobacco mosaic	7-8	A, B	3-5 da required before virus exported from inoculated leaf, but moved bi-directionally in stem within 12 hr of entry. Movement determined by progress of disease symptoms. Temp. = 11-31°C.	23

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References: [1] Schneider, I. R., and J. F. Worley. 1958. Science 127:1050. [2] Roberts, D. A. 1952. Phytopathology 42:381. [3] Severin, H. H. P. 1924. Ibid. 14:80. [4] Bennett, C. W., E. Carsner, G. H. Coons, and E. W. Brandes. 1946. J. Agr. Res. 72:19. [5] Bennett, C. W. 1934. Ibid. 48:665. [6] Bennett, C. W. 1944. Phytopathology 34:905. [7] Köhler, E. 1956. Phytopathol. Zschr. 26:147. [8] Storey, H. H. 1928. Ann. Appl. Biol., Lond. 15.1. [9] Hildebrand, E. M., and O. F. Curtis. 1942. Science 95:390. [10] De Montgrenier, H. A. 1954. Extr. Soc. Emul. Abbeville 17:11. [11] Bawden, F. C., and B. Kassanis. 1947. Ann. Appl. Biol., Lond. 34:127. [12] Bennett, C. W. 1927. Michigan Agr. Exp. Sta. Tech. Bull. 80:26. [13] Kassanis, B., T. W. Tinsley, and F. Quak. 1958. Ann. Appl. Biol., Lond. 46:11. [14] Zech, H. 1952. Planta 40:461. [15] Uppal, B. N. 1934. Ind. J. Agr. Sc. 4.865. [16] Böning, K. 1928. Zschr. Parsitenk. 1:198. [17] Holmes, F. O. 1930. Am. J. Bot. 17:789. [18] Fulton, R. W. 1941. Phytopathology 31:575. [19] Caldwell, J. 1931. Ann. Appl. Biol., Lond 18:279. [20] McCubbin, W. A., and F. F. Smith. 1927. Science 66:486. [21] Kunkel, L. O. 1939. Phytopathology 29:684. [22] Samuel, G. 1934. Ann. Appl. Biol., Lond. 21:90. [23] Capoor, S. P. 1949. Ibid. 36.307.

Part V: FLORIGEN

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Beet, sugar (Beta vulgaris)	Leaf, stem	Florigen		A, B	Separate shoots of single plant subjected to different day lengths, those receiving short days did not flower. Shoots kept in dark flowered when others on same plant were exposed to long days, thus suggesting movement of florigen into light-starved parts along with assimilates.	1
2	Cocklebur (Xanthium pennsylvanicum)	Leaf, stem	Florigen		A, B	Movement basipetally from receptor leaves subjected to short photoperiod, then transportation acropetally to plant parts maintained on long photoperiod, as indicated by induction of floral primordia. Florigen traversed approach graft, even when plants were separated by lens paper.	2
3		Leaf, stem	Florigen		A, B	Failure to translocate out of photoperiodically-induced donor branch of 2-branch plant, if either branch was girdled immediately above point of branching, thus demonstrating acropetal and basipetal movement in phloem (Floral primordia was induced on opposite branch in case of non-girdled plants.)	3
4		Leaf, stem	Florigen		A/1/, B/2/	Plants defoliated to 1 leaf and exposed to 1 short day; remaining leaf detached at various time intervals after end of 15-hr dark period. Maximum response in young leaves appeared to occur if treated leaf was retained on plant for 16 hr or more after termination of long dark period.	4
5		Leaf, stem	Florigen		A/1/, B/2/	Movement out of leaves, during 13 hr following inductive dark period, was considerably depressed if leaves were not exposed to a high intensity light. Depressing effect of light absence could be overcome by supplying sucrose to leaves.	5

/1/ Stem. /2/ Leaf.

Part V: FLORIGEN (Concluded)

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
6	Cocklebur (Xanthium saccharantum)	Leaf, stem	Florigen		A^1, B^2	Although single short-day induction period produced floral primordia, light given after long dark period increased movement from leaf to apical meristem. Without light, induction was achieved only after 8 da of continuous darkness.	6
7	Cocklebur (Xanthium commune) Soybean (Glycine max)	Leaf, stem	*Florigen* (also assimilates)	0.3[3]	A^1, B^2	Cooling stem segments to 3-5°C, or encasing with N, did not inhibit rate of florigen transport, although amount of assimilates was inhibited, and possibly the amount of florigen.	7
8	Soybean (Glycine max)	Leaf, stem	Florigen		A, B	Induction of floral primordia, as result of translocation from photoperiodically-induced leaf, was inhibited by scalding petiole of such leaf, suggesting movement in phloem.	8
9		Leaf, stem	Florigen		A, B	Chilling petiole of photoperiodically-induced leaf to 3°C inhibited outward movement of florigen, as determined by subsequent induction of floral primordia. Chilling to 5-6°C gave less inhibition, and at 10° translocation was almost equal to that of controls at 25°.	9
10	Su-Tsa (Perilla ocymoides)	Leaf	Florigen		B	Florigen formed in leaves exposed to short photoperiods and passed to shoots both via leaf veins and leaf parenchyma. Cutting leaf vein stopped outflow of nutrients, but not florigen, from leaf.	10

/1/ Stem. /2/ Leaf. /3/ Petiole

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Part VI. NITROGENOUS SUBSTANCES AND VITAMINS

	Plant	Part	Substance	Translocation: Rate cm/hr	Translocation: Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Alder, black (Alnus glutinosa)	Stem, root	Nitrogenous		A	By application of N^{15} to roots of this root-nodule plant, and by removing tissue external to xylem in a portion of the root, it was shown that upward trans- [illegible]	1
2	Alder, black (Alnus glutinosa) Locust, black (Robinia pseudoacacia) Maple, Norway (Acer platanoides)	Trunk	Nitrogenous (also carbohydrates)			[illegible]	2

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References. [1] Schneider, I. R., and J. F. Worley. 1958. Science 127:1050. [2] Roberts, D. A. 1952. Phytopathology 42:381. [3] Severin, H. H. P. 1924. Ibid. 14:80. [4] Bennett, C. W., E. Carsner, G. H. Coons, and E. W. Brandes. 1946. J. Agr. Res. 72:19. [5] Bennett, C. W. 1934. Ibid. 48:665. [6] Bennett, C. W. 1944. Phytopathology 34:905. [7] Köhler, E. 1956. Phytopathol. Zschr. 26:147. [8] Storey, H. H. 1928. Ann. Appl. Biol., Lond. 15:1. [9] Hildebrand, E. M., and O. F. Curtis. 1942. Science 95:390. [10] De Montgrenier, H. A. 1954. Extr. Soc. Emul. Abbeville 17:11. [11] Bawden, F. C., and B. Kassanis. 1947. Ann. Appl. Biol., Lond. 34 127. [12] Bennett, C. W. 1927. Michigan Agr. Exp. Sta. Tech. Bull. 80:26. [13] Kassanis, B., T. W. Tinsley, and F. Quak. 1958. Ann. Appl. Biol., Lond. 46:11. [14] Zech, H. 1952. Planta 40:461. [15] Uppal, B. N. 1934 Ind. J. Agr. Sc. 4:865. [16] Böning, K. 1928. Zschr. Parsitenk. 1:198. [17] Holmes, F. O. 1930. Am. J. Bot. 17:789. [18] Fulton, R. W. 1941. Phytopathology 31:575. [19] Caldwell, J. 1931. Ann. Appl. Biol., Lond. 18 279. [20] McCubbin, W. A., and F. F. Smith. 1927. Science 66:486. [21] Kunkel, L. O. 1939. Phytopathology 29:684. [22] Samuel, G. 1934. Ann. Appl. Biol., Lond. 21:90. [23] Capoor, S. P. 1949. Ibid 36:307.

Part V: FLORIGEN

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Beet, sugar (Beta vulgaris)	Leaf, stem	Florigen		A, B	Separate shoots of single plant subjected to different day lengths; those receiving short days did not flower. Shoots kept in dark flowered when others on same plant were exposed to long days, thus suggesting movement of florigen into light-starved parts along with assimilates.	1
2	Cocklebur (Xanthium pennsylvanicum)	Leaf, stem	Florigen		A, B	Movement basipetally from receptor leaves subjected to short photoperiod, then transportation acropetally to plant parts maintained on long photoperiod, as indicated by induction of floral primordia. Florigen traversed approach graft, even when plants were separated by lens paper.	2
3		Leaf, stem	Florigen		A, B	Failure to translocate out of photoperiodically-induced donor branch of 2-branch plant, if either branch was girdled immediately above point of branching, thus demonstrating acropetal and basipetal movement in phloem. (Floral primordia was induced on opposite branch in case of non-girdled plants.)	3
4		Leaf, stem	Florigen		A/1/, B/2/	Plants defoliated to 1 leaf and exposed to 1 short day; remaining leaf detached at various time intervals after end of 15-hr dark period. Maximum response in young leaves appeared to occur if treated leaf was retained on plant for 16 hr or more after termination of long dark period	4
5		Leaf, stem	Florigen		A/1/, B/2/	Movement out of leaves, during 13 hr following inductive dark period, was considerably depressed if leaves were not exposed to a high intensity light. Depressing effect of light absence could be overcome by supplying sucrose to leaves	5

/1/ Stem. /2/ Leaf.

Part VI: NITROGENOUS SUBSTANCES AND VITAMINS (Concluded)

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
11	Tobacco (*Nicotiana tabacum*)	Leaf, stem, root	Urea		A[2,3], B[2,3]	Radioassay after application of N^{15}-labelled urea to single leaf showed half of absorbed N^{15} transported from leaf in 24 hr. Activity present after 6 hr in leaf opposite to treated leaf, as well as in stem and root, may indicate transfer from phloem to xylem.	11
12	Tomato (*Lycopersicon esculentum*)	Leaf, stem	Total nitrogen, non-protein nitrogen, sucrose, thiamine, pyridoxine, pantothenic acid, riboflavin		B	Compounds accumulated above steamed section of stem at 2nd node in 1-4 da. Chemical analysis of bioassay for vitamins indicated that sucrose accumulated mostly above steamed section, with other compounds accumulating in varying degrees.	12
13		Leaf, stem, root	Thiamine		A, B	Bioassay of various plant parts, 1-6 da after girdling different stem loci or petioles by steam, indicated older leaves have low thiamine concentration, transport greatest to young leaves and roots.	13
14	Wheat (*Triticum* sp)	Stem	Asparagine		A	Excised stem sections (30-35 cm long) placed with upper or lower ends in solution. After 20 min, analysis of 5-cm pieces cut from each end showed N accumulation in morphological upper end regardless of which end was immersed, suggesting polar transport.	14

/2/ Stem. /3/ Leaf.

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References. [1] Bond, G 1956. J. Exp Bot. 7.387. [2] Ziegler, H. 1956. Planta 47 447. [3] Kazarian, V. O., and E. S. Avundzhyan. 1955. Doklady akad. nauk. S.S S R. 101:181. [4] Kazarian, V. O., and N. V. Balagezian. 1955. Ibid 103 337. [5] Mothes, K., and L. Engelbrecht 1954. Flora 141:356. [6] Maskell, E. J., and T. G. Mason. 1929 Ann. Bot, Lond 43 205 [7] Hay, R E., E. B. Earley, and E. E. de Turk. 1953. Plant Physiol. 28 606. [8] Kursanov, A L. 1956 Proc. Internat. Conf Peaceful Uses Atomic Energy. Geneva 12.165. United Nations, New York [9] Nelson, C. D., and P. R. Gorham. 1958. Plant Physiol., Suppl. 33.21. [10] Arisz, W. H. 1953. Acta bot néerl 2.74. [11] Volk, R., and C. McAuliffe. 1954. Proc. Soil Sc. Soc. America 18 308. [12] Bonner, J 1944 Am. J. Bot. 31.551. [13] Bonner, J. 1942. Ibid. 29·136. [14] Kursanov, A. L., and M. N Zaprometov. 1949. Doklady akad. nauk. S.S.S.R. 69 89.

Part VI. NITROGENOUS SUBSTANCES AND VITAMINS (Continued)

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
3	Ash (*Fraxinus* sp) Honeysuckle (*Lonicera* sp) Lilac (*Syringa* sp) Loxa (*Cinchona* sp)	Leaf, twig	Chlorophyll precursors		A	Darkening twig tips during spring development of leaves did not completely inhibit formation of chlorophyll, even when twigs were previously cut off. Transport of chlorophyll precursors into darkened leaves was apparently from phlelloderm cells, which simultaneously decreased in chlorophyll content.	3
4	Chrysanthemum (*Chrysanthemum* sp) Grass, pepper (*Lepidium* sp)	Stem, root	Glycocoll		A, B	By topping plants at various levels, applying glycocoll at cut surfaces, and following resultant absorption of N, polarity of movement was found to vary with developmental stage of plant and fruit.	4
5	Comfrey (*Symphytum officinale*)	Leaf, stem, root	Nitrogenous		A, B	Acropetal movement found to continue until fruiting; after fruiting, leaf proteins translocated basipetally and stored in roots largely in the form of allantoin. Root proteins did not translocate, being "protoplasmic proteins."	5
6	Cotton (*Gossypium* sp)	Leaf, stem	Nitrogenous		B[1]	Increase in total N in leaves during day and decrease during night, combined with accumulation of N above stem girdle and in semi-isolated bark flaps, suggested transport into leaves during day via xylem and from leaves both day and night via phloem.	6
7	Maize (*Zea mays*)	Leaf, stalk, grain	Nitrogenous		Into grain	Chemical analysis of various plant parts, during period of pollination to maturity, indicated plant lost 57% of total N to grain. Data suggested incorporation of nitrates with protein, or protein-like substances, and subsequent translocation to grain.	7
8	Pumpkin (*Cucurbita pepo*)	Leaf, stem	Amino acids (also sugars)		A[2], B[2,3]	1 leaf treated with known mixture of C^{14}-labelled amino acids and sugars resulted in bi-directional movement on entry into stem. Relative movement of acids and sugars into fruit dependent on stage of development.	8
9	Soybean (*Glycine max*)	Petiole, stem	Alanine, arginine, asparagine, aspartic acid, glutamic acid, glutamine, glycine, serine, urea	350-1400	B	Transport measured by introducing C^{14}-labelled substance through cut petiole, then sectioning plant after 5 min for assay. Rate different for every compound, but C^{14} concentration always decreased logarithmically from point of introduction. Basipetal transport not inhibited by a 1-7 cm steam-killed stem section, but was by 16 cm section.	9
10	Sundew (*Drosera capensis*)	Tentacle	Amino acids (including asparagine), glutamine, urea, thiourea, caffeine			Amino acids and glutamine absorbed and translocated through parenchyma of tentacles only in presence of O_2. Urea, thiourea, and caffeine translocated in absence of O_2.	10

/1/ Phloem. /2/ Stem. /3/ Leaf.

Part VI. NITROGENOUS SUBSTANCES AND VITAMINS (Concluded)

	Plant	Part	Substance	Translocation Rate cm/hr	Translocation Direction	Remarks	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
11	Tobacco (Nicotiana tabacum)	Leaf, stem, root	Urea		A/2, 3/, B/2, 3/	Radioassay after application of N^{15}-labelled urea to single leaf showed half of absorbed N^{15} transported from leaf in 24 hr. Activity present after 6 hr in leaf opposite to treated leaf, as well as in stem and root, may indicate transfer from phloem to xylem.	11
12	Tomato (Lycopersicon esculentum)	Leaf, stem	Total nitrogen, non-protein nitrogen, sucrose, thiamine, pyridoxine, pantothenic acid, riboflavin		B	Compounds accumulated above steamed section of stem at 2nd node in 1-4 da. Chemical analysis of bioassay for vitamins indicated that sucrose accumulated mostly above steamed section, with other compounds accumulating in varying degrees.	12
13		Leaf, stem, root	Thiamine		A, B	Bioassay of various plant parts, 1-6 da after girdling different stem loci or petioles by steam, indicated older leaves have low thiamine concentration; transport greatest to young leaves and roots.	13
14	Wheat (Triticum sp)	Stem	Asparagine		A	Excised stem sections (30-35 cm long) placed with upper or lower ends in solution. After 20 min, analysis of 5-cm pieces cut from each end showed N accumulation in morphological upper end regardless of which end was immersed, suggesting polar transport.	14

/2/ Stem /3/ Leaf.

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References [1] Bond, G 1956. J. Exp. Bot. 7 387. [2] Ziegler, H. 1956 Planta 47.447. [3] Kazarian, V. O., and E S Avundzhyan, 1955. Doklady akad. nauk, S S.S.R. 101:181. [4] Kazarian, V O, and N. V. Balagezian. 1955 Ibid. 103.337 [5] Mothes, K., and L. Engelbrecht. 1954. Flora 141:356. [6] Maskell, E. J., and T. G. Mason. 1929 Ann. Bot., Lond. 43 205. [7] Hay, R. E., E. R. Earley, and E. E. de Turk. 1953. Plant Physiol. 28 606. [8] Kursanov, A. L. 1956. Proc. Internat. Conf. Peaceful Uses Atomic Energy, Geneva 12 165. United Nations, New York. [9] Nelson, C. D., and P. R. Gorham. 1958. Plant Physiol., Suppl. 33 21. [10] Arisz, W. H. 1953. Acta bot néerl. 2,74. [11] Volk, R., and C. McAuliffe. 1954 Proc. Soil Sc. Soc. America 18 308. [12] Bonner, J 1944 Am. J. Bot. 31:551. [13] Bonner, J. 1942. Ibid. 29:136. [14] Kursanov, A. L., and M. N Zaprometov. 1949. Doklady akad. nauk. S.S.S R 69 89.

Part VII: ALKALOIDS AND INSECTICIDES

	Plant	Part	Substance	Translocation		Remarks	Reference
				Rate cm/hr	Direction		
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Alkaloids						
1	Alkekengi, or winter cherry (Physalis alkekengi) Belladonna (Atropa belladonna) Potato (Solanum tuberosum) Tomato (Lycopersicon esculentum)	Leaf, stem, root, tuber	Atropine, hyoscine, hyoscyamine		A, B	Approach grafts of belladonna to alkekengi, potato, or tomato, allowed to remain 3-4 mo. Alkaloids, normally elaborated in belladonna roots, translocated into basal stem, root, and tuber portions of graft partners. Such transport occurred apparently in phloem with other assimilates.	1
2	Tobacco (Nicotiana tabacum, N. rustica) Tomato (Lycopersicon esculentum)	Leaf, stem	Nicotine		A, B	Tobacco scions, grafted to tomato rootstocks and topgrafted with tomato scions, produced nicotine in basal portion of tobacco scion. Nicotine moved acropetally through upper graft, but did not pass basal graft and enter rootstock, suggesting xylem and phloem translocation, respectively. Relative contribution of tobacco root and stem to leaf nicotine varied widely.	2, 3
	Insecticides						
3	Apple (Malus sp) Bean, broad (Vicia faba) Chrysanthemum (Chrysanthemum sp) Coleus (Coleus sp)	Leaf, stem, root	Octamethyl pyrophosphoramide		A, B	Radioassay of various plant parts, after application of P^{32}-labelled compound to central leaves, indicated movement to other leaves in 8 hr and to root in 72 hr (apple). Although light had pronounced and variable effect on different plants, temperature had less effect. In beans, translocation at 10-15°C approximately equivalent to that at 27°.	4
4	Bean (Phaseolus vulgaris) Lemon (Citrus limon)	Leaf, stem	Octamethyl pyrophosphoramide; O, O-diethyl-O-mercapto-ethyl thiophosphate	10 2.5	A B	P^{32} or S^{35}-labelled compounds applied to parts of foliage or bark; translocation in stem determined by bioassay (insects feeding on various stem sections).	5

Contributor: Hull, Herbert M.

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For a comprehensive review of the subject, *see reference* 4. Values in parentheses are ranges, estimate "c" unless otherwise indicated (cf. Introduction).

	Specification	Normal Value	Trauma without Shock: No. of Subjects	Trauma without Shock: Value	Slight Shock[1]: No. of Subjects	Slight Shock[1]: Value	Severe Shock[2]: No. of Subjects	Severe Shock[2]: Value	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1	Pulse rate, beats/min	74 (51-96)	8	80 (70-98)	4	120 (100-140)	4	137 (112-205)	1
	Arterial blood pressure, mm Hg								
2	Systolic	137 (122-149)	8	137 (102-167)	4	77 (48-113)	4	63 (46-80)	1
3	Diastolic	74 (68-83)	8	69 (44-87)	4	40 (28-50)	4	32 (15-42)	1
4	Mean	97 (88-106)	8	94 (67-113)	4	54 (36-67)	4	44 (22-57)	1
	Venous blood pressure, mm H_2O								
5	Peripheral	74	8	86 (79-92)	4	77 (62-105)	4	90 (50-121)	1
6	Atrial	33	8	45 (12-70)	4	26 (10-47)	4	-8 (0 to -11)	1
	Cardiac output								
7	Cardiac index, L/min/sq m	3.4 (2.1-4.3)	8	3.6 (2.2-4.3)	4	2.5 (2.2-2.7)	4	2.1 (1.3-3.0)	1
8	Stroke volume, ml/beat	83 (63-109)	8	78 (52-100)	4	36 (33-39)	4	26 (21-35)	1
9	Total peripheral vascular resistance [illegible]	1290 [illegible]	8	1281 [illegible]35)	4	1019 (738-1452)	4	1021 (567-1468)	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	72 (58-82)	4	84 (60-100)	1
[illegible]	Plasma	1600	8	1597 (1130-2070)	4	1532 (1376-1675)	4	1125 (1033-1310)	1
12	Whole blood	2900	8	2791 [illegible]	4	2330	4	1670	1
13	RBC packed volume (hematocrit), %	47 (42-52)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	Hemoglobin, g/100 ml	16.0 (14.0-17.5)	[illegible]	(8.5-15.7)[b]	[illegible]	(8.1-14.5)[b]	[illegible]	8.8 (7.0-10.6)[b]	[illegible]
	Arterial blood								
15	O_2 content, vol %	16.6	8	15.6 (13.1-18.5)	4	12.3 (9.8-14.4)	4	11.8 (10.2-14.6)	1
16	CO_2 content, vol %	49.1	8	44.1 (42.7-50.6)	4	35.8 (32.7-40.1)	4	28.0 (16.5-39.4)	1
17	CO_2 pressure, mm Hg	38.8	8	37.4 (30.4-42.8)	4	30.5 (27.0-33.4)	4	28.4 (17.4-39.4)	1
18	O_2 saturation, %	96.0	8	94.2 (91.0-97.4)	4	90.8 (85.7-95.0)	4	94.6 (83.0-99.0)	1
19	pH	7.42	8	7.39 (7.36-7.43)	4	7.38 (7.32-7.43)	4	7.28 (7.26-7.29)	1
	Mixed venous blood								
20	CO_2 pressure, mm Hg	44.7	8	43.9 (38.3-48.2)	4	36.9 (32.0-39.5)	4	40.9 (31.4-46.7)	1
21	O_2 saturation, %	67.7	8	66.7 (58.0-76.3)	4	38.4 (35.0-42.9)	4	28.2 (14.0-49.6)	1
22	pH	7.39	8	7.36 (7.33-7.39)	4	7.32 (7.29-7.35)	4	7.22 (7.19-7.26)	1
	Plasma								
23	Protein, g/100 ml	6.5 (6.0-7.0)	15	6.6 (6.4-6.8)[b]	26	6.4 (6.2-6.6)[b]	25	6.0 (5.8-6.2)[b]	2
24	Non-protein nitrogen, mg/100 ml	33 (25-40)	18	34.0 (31.0-37.0)[b]	24	35.0 (31.4-38.6)[b]	24	44.0 (39.8-48.2)[b]	2

/1/ Characterized by decreased blood pressure of 20% or less, cool skin temperature, pale skin color, definite slowing of circulation (response to pressure, blanching), and clear but distressed mental state. /2/ Characterized by weak-to-imperceptible pulse, decreased blood pressure of 40% to non-recordable, cold skin temperature, ashen-to-cyanotic (mottled) skin color, very sluggish circulation (response to pressure, blanching), severe thirst, apathetic-to-comatose mental state.

	Specification	Normal Value	Trauma without Shock		Slight Shock[1]		Severe Shock[2]		Reference
			No. of Subjects	Value	No. of Subjects	Value	No. of Subjects	Value	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
	Plasma (concluded)								
25	Creatinine, mg/100 ml	1.0 (0.5-1.2)	18	1.0 (0.9-1.1)[b]	24	1.3 (1.1-1.5)[b]	23	2.1 (1.8-2.4)[b]	2
26	Uric acid, mg/100 ml	3.0 (1.5-3.5)	10	4.0 (2.8-5 2)[b]	16	4.5 (3.7-5.3)[b]	16	5.2 (4.1-6.3)[b]	2
27	Phosphorus, mg/100 ml	3.0 (1.6-3.5)	14	3.3 (2.8-3.8)[b]	20	3.8 (3 5-4.1)[b]	21	5.8 (4.8-6.8)[b]	2
28	Magnesium, mg/100 ml	1.8 (1.0-3.0)	11	1.7 (1.6-1.8)[b]	17	1.9 (1.8-2.0)[b]	16	2.5 (2.2-2.8)[b]	2
29	Bilirubin, mg/100 ml	(0.1-0.5)	11	0.43 (0.27-0.59)[b]	23	0.68 (0.48-0.88)[b]	21	0.47 (0.46-0.48)[b]	2
30	Glucose, mg/100 ml	(80-90)	9	134 (116-152)[b]	14	149 (131-167)[b]	13	202 (150-254)[b]	2
31	Chlorides, mEq/L	100 (97.5-104.0)	13	102 (96-108)[b]	24	101 (99.6-102.4)[b]	24	99.5 (97.7-101.3)[b]	2,3
32	CO_2 combining power, mEq/L	27 (24-31)	13	27.9 (25.9-29.9)[b]	22	26.1 (24.7-27.5)[b]	25	22.1 (20.3-23.9)[b]	2
33	Serum sodium, mEq/L	143 (139-149)			6	142.1	5	144.7	2,3

/1/ Characterized by decreased blood pressure of 20% or less, cool skin temperature, pale skin color, definite slowing of circulation (response to pressure, blanching), and clear but distressed mental state. /2/ Characterized by weak-to-imperceptible pulse, decreased blood pressure of 40% to non-recordable, cold skin temperature, ashen-to-cyanotic (mottled) skin color, very sluggish circulation (response to pressure, blanching), severe thirst, apathetic-to-comatose mental state.

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119. EFFECT OF SHOCK ON BLOOD COMPOSITION: LABORATORY ANIMALS

For a comprehensive review of the subject, see reference 27.

	Specification	Animal	Control	Shock: Gravity	Shock: Tourniquet	Shock: Noble-Collip Uncond	Shock: Noble-Collip Cond.	Shock: Traumatic	Shock: Hemorrhagic	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Glucose, mg/100 ml	Dog	85.9					86.9		1-3
2		Rat	87-95	67-196	80-150	100-190	100-125	70-195	70-195-40	4
3	Chlorides, mEq/L	Dog	107.4-115.3					115.7-116.2	108-113 4	5
4		Rabbit	107-114	95-110						6
5	Sodium, mEq/L	Dog	135-145					135-145	135-145	1
6		Dog	149-159					155-158	148-162	5
7	Calcium, mEq/L	Dog	5.1-6.6					5.1-5 4	5.4-5 8	5
8	Potassium, mEq/L	Dog	4.4-6.2					5.1-6.5	7.6-7.7	5
9		Dog	4 9					5-12		7
10		Rabbit	4 5-5.1							8,9
11	Magnesium, mEq/L	Dog	1.4-2.2					2.6-3 2	2.7-2.9	5
12	Pyruvic acid, mg/100 ml	Rat	1.4		1.2-2.2	1.5-5.0	1.5-4.0		1.4-5 0	2,4
13	Pyruvate, mEq/L	Dog	0.1-0 2					0 4-0 5	0.4-0.5	1,5
14	Lactate, mEq/L	Dog	2.1-3 9					8.0-18.8	6 0-14 6	5
15	Lactic acid, mg/100 ml	Dog	12.8					14 5		1
16		Rat	16-18		20-43	20-150	20-70			2
17	Uric acid, mg/100 ml	Rat	0.8			1 5				10
18	Plasma uric acid, mg/100 ml	Dog	0.5						4.0-5.0	11,12
19		Rat	0 6						8 7	13
20	Plasma amino acid nitrogen, mg/100 ml	Cat	4 2-7.6						4 8-11.8	14
21		Dog	2 6-5 0					5.0	5 0-7 5	1,15
22		Rat	7 0						7-40	4
23		Rat	5.0		6-12					2
24	RBC amino acid nitrogen, mg/100 ml	Rat	21						21-24	16
25	Whole blood amino acid nitrogen, mg/100 ml	Rat	14		10-30	13-23	11-17		14-40	2,4
26	Urea nitrogen, mg/100 ml	Cat	26-32					25-49		17
27		Rat	15		14 6-98.4					16
28	Creatine nitrogen, mg/100 ml	Cat	1 2-1 9					1.3-6.0		17
29		Rat	1 9			2.5				10
30	Non-protein nitrogen, mg/100 ml	Dog	15 1					19.7		1
31	HPO_4'' and H_2PO_4', mEq/L	Dog	1 2-2.6					4.0-6.5	4.3-9.7	5
32	Plasma inorganic phosphorus, mg/100 ml	Dog	4 4		4.6			4.6	3 6	1
33		Rabbit	3.3-7 2	5.2-24 6						6
34		Rat	6 92	20 0						18
35		Rat	7 5		7 5-12	6-13	6-10			2
36	RBC inorganic phosphorus mg/100 ml	Rabbit	2.2-2 7	2.6-13.0						6
37		Rat	2 35	7.70						18
38	Plasma organic phosphorus, mg/100 ml	Rabbit	0 1-0 8	0 4-8 6						6
39	RBC organic phosphorus, mg/100 ml	Rabbit	70-89	68-98						6
40	Acid-soluble organic phosphorus, mg/100 ml	Rat	9	86.9						18

	Specification	Animal	Control	Shock: Gravity	Shock: Tourniquet	Shock: Noble-Collip Uncond.	Shock: Noble-Collip Cond.	Shock: Traumatic	Shock: Hemorrhagic	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
41	Plasma acid-soluble organic phosphorus, mg/100 ml	Rat	1.20	2.35						18
42	Whole blood acid-insoluble phosphorus, mg/100 ml	Rat	20.2	15.0						18
43	Plasma iron, μg/100 ml	Dog	73						275	19
44	Plasma iron-binding capacity, μg/100 ml	Dog	170						10	19
45	Fibrinogen, %	Dog	100						70-100	20
46	Prothrombin, %	Dog	100						2.5-80	20
47	Plasma proteins, %	Dog	100						68-100	20
48	Total proteins, mg/100 ml	Cat	4.7-5.5					4.7-7.4		17
49	Ketones, mg/100 ml as acetone	Rat	3-6						6-0	21
50	Plasma aminopeptidase (glycyl-glycyl-glycine) μM/0.1 ml plasma/hr	Rat	2.0						4-11	22
51	Serum neutral fat glycerol, mM/L	Rabbit	1		2.5-9					23
52	Serum "free glycerol," mM/L	Rabbit	1		2.5-3.5					23
53	Serum phospholipid, mg/100 ml	Rabbit	90-100		180-350					23
54	Ammonia, μg/ml	Dog	0.7-1.2						1.8-4.1	24
55	Creatinine, mg/100 ml	Dog	0.97					1.03		1
56	Plasma pentose, mg/100 ml	Rat	7.0		6-18	4-17	4-8			2
57	Plasma H_2O, g/L	Dog	912-946					911-919	917-957	5
58	HCO_3, mEq/L	Dog	17.9-25 6					6.3-13.5	3.5-13.4	5
59	Base bound by protein, mEq/L	Dog	12.8-20.7					12.2-16.3 –	11.0-14.9	5
60	Total base, mEq/L	Dog	158 6-168.6					167.8-174 8	162.5-168.7	5
61	Sum of anions, mEq/L	Dog	146.6-160.7					154 3-162.0	148.6-151.8	5
62	Sum of cations, mEq/L	Dog	160.9-172.1					169.2-170.8	164.5-177.9	5
63	Cl_{RBC}/Cl_{plasma}	Dog	0.45-0.61						0.52-0.64	5
64	CO_2 pressure, mm Hg	Dog	30.0-43.7					14 7-31.8	6.8-27.9	5
65	CO_2 content, vol %	Cat	36.5					22.3		17
66	Arterial O_2 saturation, %	Cat	82-100						85-99	14
67	Venous O_2 saturation, %	Cat	69-89						5-43	14
68	Average O_2 content, right heart, vol %	Dog	12.88					5.23	4.88	25

	Specification	Animal	Control	Shock						Reference
				Gravity	Tourniquet	Noble-Collip		Traumatic	Hemorrhagic	
						Uncond.	Cond.			
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
69	Average O_2 content, portal vein, vol %	Dog	12.32					7.50	4 59	25
70	Average O_2 content, femoral vein, vol %	Dog	10.68					4.15	4.18	25
71	Average O_2 content, jugular vein, vol %	Dog	13.86					4.68	6.0	25
72	Average O_2 content, renal vein, vol %	Dog	14.54					10.83	7.62	25
73	Average O_2 content, femoral artery, vol %	Dog	17.14					16.11	13.84	25
74	pH, arterial blood	Dog	7.28-7.42					7.19-7.35	6.92-7.32	5
75		Rat	7.34	6 83						18
76	RBC packed volume (hematocrit), %	Rat	45 7		45.8-67				25-30	26
77	Lymphocytes, %	Rat	72		2.43					18

Contributors. (a) Fine, Jacob, Howard A. Frank, and Henry Korman, (b) Engel, Frank L., (c) Baez, Silvio, (d) Page, Irvine H , (e) Wiggers, Carl J.

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120. HEMODYNAMIC EFFECTS OF PATHOLOGIC CONDITIONS AND PHYSIOLOGIC AGENTS: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I: BLOOD PRESSURES

	Condition or Agent	No. of Subjects	Pressure, mm Hg: Arterial (Systemic) (Mean)	Pulmonary Capillary (Mean)	Pulmonary Artery (Mean)	Right Ventricle (Diastolic)	Right Atrium (Mean)	Ventricular Work Against Pressure kg-m/min/sq m: Left	Right	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
1	Pulmonary em-	12		9(0-14)	36(14-67)					1
2	physema	18		8(-1 to +12)	23(9-49)		5(2-9)			2
3	Mild	6	89(74-100)		15(12-19)	2(1-4)				3
4	Severe	6	95(84-118)		25(23-26)	2(0-4)				
5	Cor pulmonale	11	88(75-106)		25(15-46)	2(0-6)				
	Silicosis									
6	Mild	5	82(65-90)		20(18-21)	2(0-4)				3
7	Severe	3	87(80-93)		23(18-36)	3(0-5)				
8	Diffuse	9	87(71-100)		21(15-34)	1(-1 to +2)				
9	Mitral stenosis	12		(18-37)		(0-12)				4
10		22	87(65-123)	29(17-54)	51(23-94)	8(-3 to +33)		3.3(1.7-6.4)	1.7(0.26-3.7)	5
11		15		(15-34)	(18-56)	(0-15)				6
12		17	(63-102)		(24-81)	(1-23)				7
13		36		27(11-36)						8
14		43	(63-148)	(7-39)	(15-86)	(-2 to +20)	(-2 to +22)	(1.3-9.4)	(0.5-3.5)	9
15	Mild[1]			15	28		4.3		0.94	10
16	Moderate[2]			25	45		5.6		1.76	
17	Severe[3]			38	65		12.5		1.61	
18	Tricuspid	12		(14-35/20)[4]	(15/5-65/30)[4]	(15/-7 to 65/-5)[4]	(3-13)[5], (0-14)[6]			11
19	stenosis	5		(12-32)	(18-49)	(29/11-60/4)[4,7]	(8-18)[7]			12
20					(27/15-68/37)[4]	34/5[4,8]	(19-26)[8]			
21	Rest	3	(120/65-124/90)[4]	(19-20)	(29-51)	(40/10-78/15)[4]	(17-20)[9]			13
22					(40/23-77/43)[4]		(12-14)[10]			
23							(14-20)[11]			
24	Exercise	3	130/72[4]	(24-25)	(35-65)	53/20[4]	(25-38)[9]			
25					(56/27-86/55)[4]		(20-24)[10]			
26							(21-26)[11]			
	Tricuspid insufficiency									
27	Rest	60				75/8(26/2-136/23)[4]	10(3-29)			14
28	Exercise	60				93/12(40/5-140/25)[4]	16(6-47)			
	Aortic valvular disease									
29	Aortic	9	90(77-118)	(6-17)	(11-25)					15
30	stenosis		102/72(85/65-130/100)[4]				(0-8)	(2.3-5.2)[12]	(0.52-0.70)[13]	
31	Aortic	11	93(85-108)	(5-25)	(14-50)					
32	stenosis, plus aortic insufficiency		134/65(106/58-165/73)[4]				(1-11)	(2.7-5.5)[12]	(0.4-2.2)[13]	
33	Aortic insuf-	5	99(75-135)	(8-25)	(14-47)					
34	ficiency		174/55(140/60-240/60)[4]				(2-11)	(2.4-6.3)[12]	(0.38-1.6)[13]	

35–37	*Primary pulmonary hypertension*	10	(100/76-153/110)[4]	(3-13)	(56-105) (56-97)[14] (82/47-144/72)[4]		(5/0-26/15)[4]			16
37–38		4	(90-94) (110/70-128/88)[4]	(3-5)	(46-74) (61/31-112/50)[4]		(-1 to +11)			17
39–40		6	(76-108) (104/54-139/92)[4]	(2-11)	(48-77) (70/38-143/47)[4]	(70/14-120/4)[4]	(1-17)			18
41–43	*Patent ductus arteriosus*	16			22 34/18(20/6-77/55)[4]	34/2(23/4-79/0)[4]	1.5(0-4)			19
43–44	Pulmonary stenosis	12			11 8/9(8/-2 to 29/13)[4]	2(-2 to +5)	7(3-15)			20
45–47		24		10(5-21)	15(5-26) 23/9(14/0-33/24)[4]	78(28-114)[5]	5(-4 to +10)			21
48–49	*Interventricular septal defect*	23	(81/52-150/75)[4]	(6-12)	(16-104) (35/6-153/79)[4]	(35/-5 to 127/5)[4]	(2-9)			22
50		50	(60/40-125/80)[4]			(16/2-140/8)[4]				23
51	*Constrictive pericarditis*[15]	13		(10-28)	(24/13-45/28)[4]	(31/13-57/30)[4]	(17/11-37/31)[4]			24
52–53		5	(80-102)	(17-21)	(25-40) (33-43)[11]	(15-21)	(13-29)			25
54		10	(100/85-136/82)[4]	(15-21)	(31/18-44/23)[4]	(31/18-44/18)[4]	(15-22)			26
55	Congestive heart failure	48	102(64-163)				11(0-21)			27
56	*Acute hemorrhage*	13	65(41-74)				(-15 to +15)			28
57	Chest injury	13	73(32-104)				4(0-5)			29
58	Pericardial tamponade	7					16(-4 to +25)			30
	Acute hypoxia									31
59	Before	28[16]	100	10	19					
60	After	28[16]	100	10	25					
61	Before	8[17]	98	5	10			5.0		32
62	After	8[17]	93	5	15			6.0		
63	Before	12[18]	98	8	24			4.7	1.06	
64	After	12[18]	102	9	32(10-73)			5.6	1.64	
65	Before	24[19]	95(73-130)	18(7-34)	34(17-84)					33
66	After	24[19]	93(58-122)	19(6-35)	43					
	100% oxygen									34
67	Before			5	25					
68	After			4	20					
	Norepinephrine									35
69	Before	8[17]	90	5	13					
70	After	8[17]	140	13	23					
71	Before	8[20]	144	8	17					
72	After	8[20]	198	20	28					
73	Before	12	100	9	16					36
74	After	12	125	15	21					

/1/ With pulmonary artery systolic pressure <50 mm Hg. /2/ With pulmonary artery systolic pressure >50 mm Hg. /3/ With right ventricular failure. /4/ Systolic/diastolic. /5/ A wave. /6/ V wave. /7/ Rest. /8/ Exercise. /9/ Systolic. /10/ Early diastolic. /11/ Late diastolic. /12/ Systemic. /13/ Pulmonary. /14/ Breathing 100% O_2. /15/ Diagnostic criteria: (1) M- or W-shaped pattern of right atrial pressure, (2) an early diastolic dip followed by a rapid rise of right ventricular pressure to form a plateau, (3) ratio of right ventricular diastolic pressure to right ventricular systolic pressure of 33 to 40%. /16/ 22 normal subjects, 6 patients. /17/ Normal subjects. /18/ Patients. /19/ Patients with mitral stenosis. /20/ Hypertensive patients.

Part I BLOOD PRESSURES (Concluded)

	Condition or Agent	No. of Subjects	Pressure, mm Hg Arterial (Systemic) (Mean)	Pulmonary Capillary (Mean)	Pulmonary Artery (Mean)	Right Ventricle (Diastolic)	Right Atrium (Mean)	Ventricular Work Against Pressure kg-m/min/sq m Left	Right	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Saline infusion, intravenous									
75	Before	12		5	12					
76	After	12		13	20					
77	Before	10	(76-110)							37
78			(106/60-155/80)[4]				(-2 to +4)			
79	After	10	(78-109)							38
80			(107/64-158/80)[4]				(2-8)			
	5% albumin infusion, intravenous									
81	Before	7	(66-113)							38
82			(107/47-163/86)[4]				(-1 to +5)			
83	After	7	(47-84)							
84			(107/69-166/113)[4]				(3-14)			

/4/ Systolic/diastolic.

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Part II. BLOOD FLOW AND RESISTANCE

	Condition or Agent (A)	No of Subjects (B)	Blood Flow: Cardiac Index L/min/sq m (C)	Blood Flow: Stroke Index ml/beat/sq m (D)	A-V O_2 Difference ml/L (E)	Resistance, dynes sec/(cm^5): Total Arterial (Systemic) (F)	Resistance, dynes sec/(cm^5): Total Pulmonary (G)	Resistance, dynes sec/(cm^5): Pulmonary Vascular (H)	Reference (I)
1	Pulmonary emphy-	12	3.0(1.9-4.9)		41(28-63)		590(145-1788)	450(73-1522)	1
2	sema	18	3.5(2.3-6.6)				390(70-834)	250(25-666)	2
3	Mild	6	3.2(2.7-3.6)						3
4	Severe	6	3.6(2.4-4.5)						
5	Cor pulmonale	11	3.4(2.4-4.6)						
	Silicosis								
6	Mild	5	2.8(2.4-3.3)						3
7	Severe	3	2.8(2.4-3.0)						
8	Diffuse	9	4.0(3.2-4.9)						
9	Mitral stenosis		(1.4-3.6)					(204-1480)	4
10			2.8(1.4-5.2)	30(9-54)	57(30-86)	1799(775-3760)	1111(212-2372)	491(51-1480)	5
11		15	(1.3-4.2)					(90-1440)	6
12		17	(1.36-3.23)		(49-123)				7
13		36	2.07(1.47-3.53)					(59-2065)	8
14		43	(1.3-5.5)	(11-24)	(26-89)	(734-4460)	(137-2805)	(64-1443)	9
15	Mild		2.78		52		514	231	10
16	Moderate		3.07		48		822	424	
17	Severe		2.24		63		1627	775	
18	Tricuspid stenosis	12	(2.6-6.8)[1]						11
19		5	(2.10-3.40)	(28-39)			(320-950)	(110-330)	12
20	Rest	3	(0.8-2.2)		(77-104)				13
21	Exercise	3	(2.2-2.7)		(105-162)		643(110-2109)		14
	Tricuspid insufficiency								
22	Rest	60	1.94(1.15-3.11)						
23	Exercise	60	2.29(1.16-6.25)						
	Aortic valvular disease								
24	Aortic stenosis	9	(2.0-5.1)	(19-54)	(33-62)	(1280-4350)		(73-532)	15
25	Aortic stenosis, plus aortic insufficiency	11	(2.6-5.2)	(29-79)	(41-83)	(1310-3002)		(71-690)	
26	Aortic insufficiency	5	(2.2-3.9)	(26-54)	(37-82)	(1465-2950)		(154-458)	
27	Primary pulmonary	10	(0.9-2.3)[2]				(1080-6390) (950-5900)[3]		16
28	hypertension				(54-97)	(1742-2669)	(1051-2193)	(983-1209)	17
29		4	(1.6-2.8)		(10-37)	(1110-3620)	(1080-3280)	(930-1650)	18
30		6	(1.08-3.73)						19
31	Patent ductus	16	3.9(1.7-5.5)[4]						
32	arteriosus		8.5(3.5-14.9)[5]						20
33	Pulmonary stenosis	12	3.4(1.8-5.2)				218(84-379)	110(24-285)	21
34		24	4.0(2.7-6.3)				(101-3080)		22
35	Interventricular septal	23	(1.2-12.0)[4,6]						
36	defect		(1.5-26.9)[5,7]						

/1/ Cardiac output, L/min. /2/ Pulmonary blood flow, L/min/sq m = 1.2-4.2 breathing room air, 1.3-4.7 breathing 100% O_2. /3/ Breathing 100% O_2. /4/ Systemic. /5/ Pulmonary. /6/ Blood O_2 content = 14.6-31.4 vol %, blood O_2 saturation = 69.2-101%. /7/ Blood O_2 content = 11.6-22.6 vol %, blood O_2 saturation = 51.5-90%.

Part I: BLOOD PRESSURES (Concluded)

	Condition or Agent	No. of Subjects	Pressure, mm Hg: Arterial (Systemic) (Mean)	Pulmonary Capillary (Mean)	Pulmonary Artery (Mean)	Right Ventricle (Diastolic)	Right Atrium (Mean)	Ventricular Work Against Pressure kg-m/min/sq m: Left	Right	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
	Saline infusion, intravenous									
75	Before	12		5	12					37
76	After	12		13	20					
77	Before	10	(76-110)							38
78			(106/60-155/80)[4]				(-2 to +4)			
79	After	10	(78-109)							
80			(107/64-158/80)[4]				(2-8)			
	5% albumin infusion, intravenous									38
81	Before	7	(66-113)							
82			(107/47-163/86)[4]				(-1 to +5)			
83	After	7	(47-84)							
84			(107/69-166/113)[4]				(3-14)			

/4/ Systolic/diastolic.

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Part II. BLOOD FLOW AND RESISTANCE (Concluded)

	Condition or Agent	No. of Subjects	Blood Flow: Cardiac Index L/min/sq m	Blood Flow: Stroke Index ml/beat/sq m	Blood Flow: A-V O_2 Difference ml/L	Resistance, dynes sec/(cm^5): Total Arterial (Systemic)	Resistance: Total Pulmonary	Resistance: Pulmonary Vascular	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
37	Constrictive pericarditis	13	(1.27-3.91)						23
38		5	(1.7-3.3)	(43-104)/8/					24
39		10	(1.18-4.57)						25
40	Congestive heart failure	48	2.0(1.3-4.0)		68(32-108)				26
41	Acute hemorrhage	13	2.5(1.6-5 0)		54(26-105)	1300(700-2427)			27
42	Chest injury	13	3.8(1.8-5.0)		48(35-62)	1000(490-1320)			28
43	Pericardial tamponade	7	2.7(1.5-4.0)		61(52-84)	1250(930-1960)			29
	Acute hypoxia								
44	Before	28	3.0		46			133	30
45	After	28	3.1		43			202	
46	Before	8	3.4			1214		66	31
47	After	8	4.4			962		119	
48	Before	12	3.2			1494		262	
49	After	12	3.8			1450		416	
50	Before	24	3.14(1.42-5.22)	39(19-72)	46.7(28.5-70.4)	1540(690-3900)	610(120-1500)	279(40-880)	32
51	After	24	3.63(1.81-10.75)	39(20-101)	41.9(13.1-61.3)	1370(315-3140)	690(160-1550)	418(80-980)	
	100% oxygen								
52	Before		5.6/1/				417		33
53	After		4.8/1/				366		
	Norepinephrine								
54	Before	12	3.0		40	1500		109	34
55	After	12	2.9		41	2090		118	
	Saline infusion, intravenous								
56	Before	12	3.6		43				35
57	After	12	4.3		38				
58	Before	10	(2.3-5.0)		(23-46)				36
59	After	10	(2.4-6.3)		(22-49)				
	5% albumin infusion, intravenous								
60	Before	7	(2.5-4.6)		(26-56)				36
61	After	7	(2.6-5.9)		(22-49)				

/1/ Cardiac output, L/min. /8/ Stroke volume, ml/beat.

Contributor: Yu, Paul N.

References. [1] Dexter, L., J. L. Whittenberger, R. Gorlin, B. M. Lewis, F. W. Haynes, and R. J. Spiegl. 1951. Tr. Ass. Am. Physicians 65:226. [2] Yu, P. N., F. W. Lovejoy, Jr., H. A. Joos, R. E. Nye, Jr., and W. S. McCann. 1953. J. Clin. Invest. 32:130. [3] Harvey, R. M., M. I. Ferrer, D. W.

121. CHRONIC CONSTRICTIVE PERICARDITIS: MAN (Concluded)

Part II INCIDENCE OF ACCOMPANYING CONDITIONS (Concluded)

	Condition	No. of Subjects	Incidence %	Reference
	(A)	(B)	(C)	(D)
9	Cyanosis	204	39	2-5
10	Pulsus paradoxus	59	90	4,6,7
11	Atrial fibrillation or flutter	206	27	1-4,6,8
12	Protodiastolic sound	98	42	5,8,9
13	Right ventricular diastolic dip	26	96	3,9,10
14	Albuminuria	78	22	2,5
15	Pericardial calcification[1]	267	52	2,4,8
16	Enlarged cardiopericardial silhouette[1]	235	50	1-4,8
17	Diminished cardiac pulsations[1]	192	93	1-4,6,8
18	Pleural effusion[1]	240	61	1-6,8
19	Low voltage[2]	22	95	2
20	Low, inverted T waves[2]	22	77	2

/1/ Roentgenographic determination. /2/ Electrocardiographic determination

Contributors: McGuire, Johnson, and Robert A. Helm

References [1] Chambliss, J. R., E. J. Jaruszewski, B. L. Brofman, J. F. Martin, and H. Feil. 1951. Circulation, N. Y 4 816. [2] Deterling, R. A , and G. H. Humphries. 1955. Ibid. 12 30. [3] Harrington, S. W. 1944. Ann. Surg 120 468. [4] Stewart, H J., J R. Carty, and J. R. Seal 1943. Am. J. Roentg 49 349. [5] Mortensen, V., and E. Warburg 1948. Acta med. scand. 131:203. [6] Blalock, A., and C. S. Burwell. 1941. Surg Gyn. Obst 73 433. [7] Dalton, J. C., R. J. Pearson, Jr., and P. D. White. 1956. Ann. Int. M. 45 445. [8] Paul, O , B. Castleman, and P. D. White. 1948. Am. J. M. Sc. 216:361. [9] McKusick, V. A. 1952. Bull. Johns Hopkins Hosp. 90 3. [10] Wilson, R. H., W. Hoseth, C. Sadoff, and M. E. Dempsey. 1954. Am. Heart J. 48,671

122 HEMODYNAMICS OF ACUTE CARDIAC TAMPONADE. MAN

Values in parentheses are ranges, estimate "c" (cf Introduction).

	Variable	No of Subjects	Value	Reference
	(A)	(B)	(C)	(D)
1	Heart rate, beats/min	20	116(76-150)	1,2
2	Respiratory rate, breaths/min	13	27(22-35)	1
	Arterial blood pressure, mm Hg			1-3
3	Systolic	21	86	
4	Diastolic	21	57	
5	Respiratory variation in arterial systolic pressure, mm Hg	7	26(16-49)	2
6	Venous pressure, mm saline	13	240	1
7	Arterial O_2 saturation, %	3	94(92-97)	3
8	Cardiac index (Fick), L/min/sq m	7	2.5(1 5-4 0)	2,3
	Pulmonary artery pressure, mm Hg			3
9	Systolic	3	29(20-39)	
10	Diastolic	3	20(11-25)	
	Right ventricular pressure, mm Hg			3
11	Systolic	3	29(20-39)	
12	Diastolic	3	13(8-17)	
13	Right ventricular pressure ratio (diastolic·systolic), %	3	46(38-61)	3
14	Right atrial pressure (mean), mm Hg	10	12.1(8-23)	2,3
15	Superior vena caval pressure (mean), mm Hg	3	16.7(8-23)	3

Contributors McGuire, Johnson, and Robert A Helm

References [1] McGuire, J , and E. J McGrath. 1941 Tr. Ass Am Physicians 56.194 [2] Warren, J. V., E S Brannon, E A Stead, Jr., and A J Merrill 1946 Am. Heart J. 31 418. [3] Wilson, R. H , W. Hoseth, C. Sadoff, and M E Dempsey. 1954 Ibid 48 671.

121. CHRONIC CONSTRICTIVE PERICARDITIS. MAN

Part I: HEMODYNAMICS

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Variable	No. of Subjects[1]	Value	Reference
	(A)	(B)	(C)	(D)
1	Age, yr	125	47.4(6-77)	1-8
2	Heart rate, beats/min	89	96(60-150)	1,2
	Arterial blood pressure, mm Hg			2,5-7,9,10
3	Systolic	98	110(80-210)	
4	Diastolic	98	78(50-120)	
5	Pulse pressure, mm Hg	61	33(10-70)	2
6	Circulation time (arm to tongue), sec	56	26(10-88)	2,3,8
7	Vital capacity, ml	49	1885(575-4000)	2
8	Venous pressure, cm H_2O	107	25.8(13-41)	1-5,8-12
9	White blood cell count	61	6,870(4,300-13,300)	2
10	Blood urea nitrogen, mg %	61	12.2(6.0-22.5)	2
11	Serum protein, g %	59[2], 15[3]	6.17[2](3.8-8.8)[3]	2,3[2],3[3]
12	Serum albumin, g %	39[2], 15[3]	3.46[2](2.5-5.5)[3]	2[2],3[3]
13	Serum globulin, g %	39[2], 15[3]	2.61[2](1.6-3.8)[3]	2[2],3[3]
14	Blood volume[4], ml/kg	19	93.5(71-112)[5]	2
15	Arterial O_2 saturation, %	27	93.9(85-100)	5,7,13
16	Cardiac index (Fick), L/min/sq m	30	2.39(1.2-3.9)	5,7,13
17	Pulmonary artery "wedge" pressure (mean), mm Hg	14	18.1(8-28)	5,7,13,14
	Pulmonary artery pressure, mm Hg			5,7,13,14
18	Systolic	29	34.5(18-45)	
19	Diastolic	29	18.5(8-31)	
	Right ventricular pressure, mm Hg			5,7,8,13,14
20	Systolic	35	37.4(18-57)	
21	Diastolic	35	17.2(8-32)	
22	Right atrial pressure (mean), mm Hg	18	17.9(10-25)	5,7,13,14
23	Superior vena caval pressure (mean), mm Hg	9	18.0(15-22)	7
24	Glomerular filtration rate, ml/min	7	107.7(80-141)	13
25	Renal plasma flow, ml/min	7	350.1(171-595)	13
26	Filtration fraction	7	0.312(0.242-0.454)	13

/1/ Distribution among the sexes in 257 cases of chronic constrictive pericarditis: 75% males, 25% females [1-6,8,9]. /2/ and /3/ Matching footnotes in column D indicate source of data. /4/ Vital-red technique. /5/ Normal range, 70-100 ml/kg.

Contributors: McGuire, Johnson, and Robert A. Helm

References: [1] Blalock, A., and C. S. Burwell. 1941. Surg. Gyn. Obst. 73:433. [2] Chambliss, J. R., E. J. Jaruszewski, B. L. Brofman, J. F. Martin, and H. Feil. 1951. Circulation, N. Y. 4:816. [3] Deterling, R. A., and G. H. Humphries. 1955. Ibid. 12:30. [4] Harrington, S. W. 1944. Ann. Surg. 120:468. [5] Sawyer, C. G., C. S. Burwell, L. Dexter, E. C. Eppinger, W. T. Goodale, R. Gorlin, D. E. Harken, and F. W. Haynes. 1952. Am. Heart J. 44:207. [6] Stewart, H. J., J. R. Carty, and J. R. Seal. 1943. Am. J. Roentg. 49:349. [7] Wilson, R. H., W. Hoseth, C. Sadoff, and M. E. Dempsey. 1954. Am. Heart J. 48.671. [8] Yu, P. N. G., F. W. Lovejoy, Jr. H. A. Joos, R. E. Nye, Jr. and E. B. Mahoney. 1953. Circulation, N. Y. 7:102. [9] Mortensen, V., and E. Warburg. 1948. Acta med. scand. 131:203. [10] Cushing, E. H., and H. S. Feil. 1936. Am. J. M. Sc. 192:327. [11] Burwell, C. S., and A. Blalock. 1938. J. Am. M. Ass. 110:265. [12] Burwell, C. S., and D. Flickinger. 1935. Arch. Int. M. 56:250. [13] McKusick, V. A. 1952. Bull. Johns Hopkins Hosp. 90:3. [14] Lin, T. K., and M. Anache. 1956. Am. Heart J. 51:340.

Part II INCIDENCE OF ACCOMPANYING CONDITIONS

	Condition	No. of Subjects	Incidence %	Reference
	(A)	(B)	(C)	(D)
1	Dyspnea	273	76	1-5
2	Orthopnea	109	34	1-3
3	Cough	46	41	2,5
4	Precordial pain	45	31	2,5
5	Edema	295	73	1-6
6	Ascites	247	80	1-6
7	Hepatomegaly	93	99	1-6
8	Distended cervical veins	125	86	1,3-5

Part I. ANEMIA, ARTERIO-VENOUS COMMUNICATION, BERIBERI, PAGET'S DISEASE, THYROTOXICOSIS (Concluded)

Contributor: Helm, Robert A.

References: [1] Bishop, J. M., K. W. Donald, and O. L. Wade. 1955. Clin. Sc., Lond 14·329. [2] Brannon, E. S., A. J. Merrill, J. V. Warren, and E. A. Stead, Jr. 1945. J. Clin. Invest. 24 332. [3] Sharpey-Schafer, E. P. 1944. Clin. Sc., Lond. 5 125. [4] Sharpey-Schafer, E. P. 1945. Lancet, Lond. 2.296. [5] Cohen, S. M., O. G. Edholm, S. Howarth, J. McMichael, and E. P. Sharpey-Schafer. 1948. Clin. Sc., Lond. 7.36. [6] Burwell, C. S., and L. Dexter. 1947. Tr. Ass. Am. Physicians 60·59. [7] Fowler, N. O. 1953 Ann. Int. M. 38:478. [8] Lahey, W. J., D. B. Arst, M. Silver, C. R. Kleeman, and P. Kunkel. 1953. Am J. Med. 14·248. [9] Porter, R. R., and R. S Downs. 1942. Ann. Int. M. 17 645. [10] Campbell, J. A., L. A. Selverstone, and D. L. Donovan. 1951. J. Clin. Invest. 30 632. [11] Howarth, S. 1953. Clin. Sc., Lond. 12:271. [12] Rappaport, E., H. Kuida, L. Dexter, P. H. Henneman, and F. Albright. 1957. Am. J. Med. 22.252. [13] Myers, J. D., E. S. Brannon, and B. C. Holland. 1950. J. Clin. Invest. 29·1069.

Part II. CHRONIC PULMONARY EMPHYSEMA, WITH AND WITHOUT COR PULMONALE

For additional information on the subject, see references 4-9.

	Variable	Emphysema: Without Cor Pulmonale		Emphysema: With Chronic Cor Pulmonale: Compensated		Emphysema: With Chronic Cor Pulmonale: Decompensated		Reference
		No. of Subjects	Value	No. of Subjects	Value	No. of Subjects	Value	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Ratio of residual volume to total capacity, %	28	62(40-86)	18	56(23-83)	5	56(42-73)	B-E,1,2;F, G,2
2	Arterial O_2 saturation, %	28	86(70-98)	22	79(62-90)	12	67(51-88)	B,C,1,2;D, E,1-3,F, G,2,3
3	Maximal breathing capacity, % predicted	11	39(22-58)	11	43(21-77)	5	26(13-51)	B-G,2
4	CO_2 pressure, mm Hg	12	46(37-55)	11	50(38-58)	6	64(53-72)	
5	Hematocrit, %	27	44(34-51)	22	52(47-57)	12	63(54-70)	
6	Total blood volume, ml/sq m	28	3024(2380-3740)	22	3630(2909-4035)	12	4893(3820-6070)	B,C,1,2,D, E,1-3;F, G,2,3
7	Pulmonary artery pressure (systolic/diastolic), mm Hg	27	32/17 (23-71/7-37)	22	44/22 (26-76/8-37)	12	72/34 [illegible]	
8	[illegible]							
	[illegible]	[illegible]	3.34(2.05-4.53)	11	3.39(2.39-4.63)	6	3.28(1.70-6.06)	

Contributors: (a) Helm, Robert A., (b) Fowler, Noble O.

References: [1] Borden, C W., R H. Wilson, R. V. Ebert, and H. S. Wells. 1950. Am. J. Med. 8 701. [2] Harvey, R M., M. I. Ferrer, D W. Richards, Jr., and A Cournand. 1951. Ibid. 10·719 [3] Fowler, N. O., R N. Westcott, R C Scott, and E. Hess. 1952. Circulation, N Y. 6·888. [4] Dexter, L., et al. 1951. Tr. Ass. Am Physicians 64 226. [5] Yu, P N., et al. 1953. J. Clin. Invest. 32 130. [6] Hecht, H. H. 1956. Circulation, N. Y. 14.265 [7] Whitaker, W. 1954. Q J Med., Oxf. 47:57. [8] Mounsey, P., et al. 1952. Brit. Heart J. 14 153 [9] Denolin, H., and J. Lequime. 1951 Arch. mal coeur 5 391.

123. HEMODYNAMICS IN CONDITIONS OF HIGH CARDIAC OUTPUT: MAN

Cardiac output determined by catheterization. Values in parentheses are ranges, estimate "c" (cf. Introduction).

Part I ANEMIA, *ARTERIO-VENOUS COMMUNICATION*, BERIBERI, *PAGET'S DISEASE*, THYROTOXICOSIS

	Variable	No. of Subjects	Value	Reference
	(A)	(B)	(C)	(D)
	Anemia			
1	Age, yr	16♂, 34♀	45(17-53)	1-4
2	Hemoglobin, g/100 ml	49	5.5(1.9-11.2)	
3	Heart rate, beats/min	48	91(63-124)	
4	Arterial blood pressure (systolic/diastolic), mm Hg	47	140/59(94-185/40-99)	
5	O_2 consumption, ml/min	46	249(167-348)	1-3
6	Arterio-venous O_2 difference, vol %	46	3.0(1.8-5.1)	
7	Cardiac output, L/min	50	8.63(3.9-14.3)	1-4
8	Cardiac index, L/min/sq m	28	5.26(2.5-8.8)	1, 2
9	Cardiac output, L/min (Hb <6 g/100 ml)	34	9.07(6.9-13.6)	1-4
	Arterio-venous Communication			
10	Age, yr	13♂	28(20-51)	1, 5
11	Heart rate, beats/min	13	80(55-90)	
12	Arterial blood pressure (systolic/diastolic), mm Hg	12	120/63(98-134/55-78)	
13	O_2 consumption, ml/min	13	308(243-367)	
14	Arterio-venous O_2 difference, vol %	13	2.8(2.0-4.2)	
15	Cardiac output, L/min	13	11.65(6.4-16.1)	
	Beriberi			
16	Age, yr	4♂, 1♀	29(23-35)	6-9
17	Heart rate, beats/min	5	104(89-124)	
18	Arterial blood pressure (systolic/diastolic), mm Hg	5	128/69(100-150/55-84)	
19	*Pulmonary artery pressure (systolic/diastolic)*, mm Hg	3	44-25(34-64/15-36)	6-8
20	*Venous pressure, cm H*...	4	26.6(19.5-31.0)	6, 8, 9
		5	11.4(9-14)	6-9
		5	310(259-355)	
	vol %	5	3.4(2.2-6.2)	
		5	10.47(4.7-16.1)	
	Cardiac index, L/min/sq m	5	5.67(2.9-7.8)	7-10
	Paget's Disease[1]			
26	Age, yr	7♂, 11♀	63(41-77)	11, 12
27	Heart rate, beats/min	18	79(60-88)	
28	Arterial blood pressure (systolic/diastolic), mm Hg	17	140/73(116-160/55-90)	
29	O_2 ...	18	268(147-328)	
	vol %	18	3.5(2.0-5.5)	
		18	7.66(3.8-13.3)	
		12	33(10-64)	11
	...mstrong units[2]	12	57(11.5-120.5)	
	...y units[3]	6	56(17-114)	12
	...l involvement >30%)	11	9.21(7.1-13.3)	11, 12
	...output, L/min (skeletal involvement <30%)	7	5.21(3.8-6.3)	
37	Cardiac output, L/min (alkaline phosphatase >45 K-A units[2])	15	8.16(3.8-13.3)	
38	Cardiac output, L/min (alkaline phosphatase <45 K-A units[2])	3	5.13(4.2-5.7)	11
	Thyrotoxicosis			
39	Age, yr	10♂, 19♀	35(12-62)	1, 13
40	Heart rate, beats/min	26	104(64-150)	
41	Arterial blood pressure (systolic/diastolic), mm Hg	25	142/75(106-183/50-96)	
42	*Pulmonary artery pressure* ... mm Hg	14	20.6(13-27)	
	... mm Hg	20	36.5(23-54)	13
		20	2.5(-1 to +6)	
		24	35.8(27.5-42.1)	
		29	325(234-476)	1, 13
		29	3.7(2.2-4.9)	
		29	5.65(3.3-7.3)	
		29	+61(+23 to +111)	

/1/ Osteitis deformans generalized /2/ Amount of phosphatase which, when allowed to act upon an excess of disodium phenylphosphate at pH 9 for 30 minutes (37.5°C), will liberate 1 mg of phenol. /3/ Amount of phosphatase required to liberate 1 mg of phosphorus in the form of the phosphorus ion, in 1 hour of incubation with a substrate of sodium *β-glycerophosphate*.

125. HEMODYNAMICS OF COR PULMONALE: MAN

Values in parentheses are ranges, estimate "b" (cf. Introduction).

	Condition	No. of Subjects	Body Surface Area sq m	Cardiac Index L/min/sq m	Stroke Volume ml/beat	O_2 Consumption ml/min/sq m	Arterio-venous O_2 Difference vol %	Arterial O_2 Concentration vol %	Arterial O_2 Saturation %	Arterial CO_2 Pressure mm Hg	Pulmonary Artery Pressure mm Hg Systolic	Pulmonary Artery Pressure mm Hg Diastolic	Pulmonary Artery Pressure mm Hg Mean	Right Ventricular Pressure mm Hg Systolic	Right Ventricular Pressure mm Hg Diastolic	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
1	Normal			3.1 (2.7-3.5)	70	130	4.2 (3.8-4.8)	19	96 (94-98)	40 (37-43)	30	10	15	30	5	1
2	Obstructive pulmonary emphysema	11[1]	1.56	3.6	64	147	4.3	15.6	81	50	40	16	25		22[2]	1
3		43[3]	1.59	4.7	71	165	3.5	11.6	58	65	71	36	49		13[2]	1
4		11[4]	1.76	3.0		129	4.8		63				48			2
5		12[4]		2.7 (1.7-3.8)		132	4.9		76		64	33	44	56	9[2]	3
6	Alveolar-capillary diffusion block	12[5]	1.56	3.5 (2.6-4.9)	63	151	4.1 (3.1-5.6)		93 (78-98)	38	36	14	23			4
7	Primary pulmonary hypertension[6]	3	1.55	1.9	33	126	6.8	18.2	98		81	43	62	80	13[2]	5
8		10		1.6				20.0	92 (80-97)		111	59	75			6
9		3[7]									159	105		160	0[2]	7
10		9									95	59	77	97	11[2]	8

/1/ Recently in cardiac failure. /2/ End diastolic pressure. /3/ In reversible cardiac failure. /4/ In cardiac failure at time of observation. /5/ Adults of various ages, distribution among the sexes approximately equal. /6/ Majority of observations in young patients, most of whom were females. /7/ Advanced cases, representing extremes in this condition.

Contributor: Samet, Philip

References: [1] Harvey, R. M., M. I. Ferrer, D. W. Richards, Jr., and A. Cournand. 1951. Am. J. Med. 10:719. [2] Lewis, C. S., A. J. Samuels, M. C. Daines, and H. H. Hecht. 1952. Circulation, N. Y. 6:874. [3] Fowler, N. O., R. N. Westcott, R. C. Scott, and E. Hess. 1952. Ibid. 6:888. [4] Austrian, R., J. H. McClement, A. D. Renzetti, Jr., K. W. Donald, R. L. Riley, and A. Cournand. 1951. Am. J. Med. 11:667. [5] Dresdale, D. T., M. Schultz, and R. J. Michtom. 1951. Ibid. 11:686. [6] Shepherd, J. I., J. E. Edwards, H. B. Burchell, H. J. C. Swan, and E. H. Wood. 1957. Brit. Heart J. 19:70. [7] Schafer, H., R. C. Blain, and R. J. Bing. 1956. Ann. Int. M. 44:505. [8] Chapman, D. W., J. P. Abbott, and J. Latson. 1957. Circulation, N. Y. 15:35.

126. CEREBRAL FUNCTION IN COR PULMONALE WITH CO_2 RETENTION: MAN

	Condition	Blood Flow ml/100 g/min Normal	Blood Flow ml/100 g/min Patient	Vascular Resistance mm Hg/ml/100 g/min Normal	Vascular Resistance mm Hg/ml/100 g/min Patient	O_2 Consumption ml/100 g/min Normal	O_2 Consumption ml/100 g/min Patient	Mean Arterial Pressure mm Hg Normal	Mean Arterial Pressure mm Hg Patient	Arterial CO_2 Pressure mm Hg Normal	Arterial CO_2 Pressure mm Hg Patient	Arterial HbO_2 Saturation % Normal	Arterial HbO_2 Saturation % Patient	Arterial pH Normal	Arterial pH Patient	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)
1	Breathing air[1]	50	68	1.9	1.52	3.0	2.7	93	91	40	58	96	68	7.40	7.36	1
2	Breathing O_2[1]	44	79	2.1	1.46	3.2	2.7	91	89		70	100+	93		7.24	1
3	Resting[2]	55	56	1.82	1.70	3.64	3.33	97	90		49	96			7.38	2
4	Exercising[2]		53		1.85		2.93		103		54				7.34	2

/1/ 8 normal controls, 9 patients. [1] /2/ Unstated number of controls, 9 patients [2]

Contributor: Samet, Philip

References: [1] Patterson, J. L., Jr., A. Heyman, and T. W. Duke. 1952. Am. J. Med. 12:382. [2] Scheinberg, P., I. Blackburn, M. Saslaw, M. Rich, and G. Baum. 1953. J. Clin. Invest. 32:720.

Part I: CARDIAC INDEX AND PULMONARY ARTERY PRESSURE VS ARTERIAL O_2 SATURATION

Measurements made under resting conditions. Cardiac output calculated from O_2 content of mixed venous blood and arterial blood, and from O_2 uptake by the lungs (sample of mixed venous blood obtained from pulmonary artery or right ventricle through a catheter). Cardiac index then calculated by dividing cardiac output by body surface area in square meters. Pressure measured, through a catheter in the pulmonary artery, with a high frequency manometer. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Arterial O_2 Saturation %	Cardiac Index[1] L/min/sq m	Pulmonary Artery Pressure[2] mm Hg	Reference
	(A)	(B)	(C)	(D)
1	Above 90	3.7(2.2-6.6)	18(9-28)	B, 1-5; C, 1-4
2	85-90	3.2(2.3-5.4)	26(15-38)	B, 1-6; C, 1-4, 6
3	80-85	3.6(1.9-5.8)	28(13-43)	B, 1-6; C, 1, 2, 4, 6
4	75-80	3 6(2.7-4.9)		1-3, 5, 6
5	70-80		34(16-57)	1, 2, 6
6	70-75	3.8(2.6-6.4)		2, 3, 5, 6
7	70 and below	3.7(1.7-6.1)	53(44-74)	B, 1, 3-6; C, 1, 4, 6

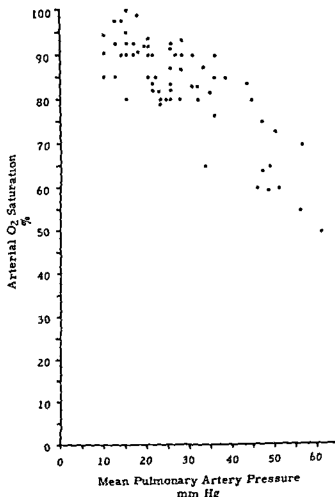
/1/ No demonstrable relationship in any one patient between cardiac index and arterial O_2 saturation. /2/ Integrated mean pressure.

Contributors: (a) Ebert, Richard V., (b) Stone, Daniel J.

References: [1] Harvey, R. M., M. I. Ferrer, D. W. Richards, Jr., and A. Cournand. 1951. Am. J. Med. 10:719. [2] Yu, P. N. G., F. W. Lovejoy, Jr., H. A. Joos, R. E. Nye, Jr., and W. S. McCann. 1953. J. Clin. Invest. 32:130. [3] Dexter, L., J. L. Whittenberger, R. Gorlin, B. M. Lewis, F. W. Haynes, and R. J. Spiegl. 1951. Tr. Ass. Am. Physicians 64:226. [4] Sancetta, S. M. 1955. Am. Heart J 49:501. [5] Mounsey, J. P. D., L. W. Ritzman, N. J. Selverstone, W. A. Briscoe, and G. A. McLemore. 1952. Brit. Heart J. 14:153. [6] Fowler, N. O., R. N. Westcott, R. C. Scott, and E. Hess. 1952. Circulation, N. Y. 6:888.

Part II. MEAN PULMONARY ARTERY PRESSURE VS ARTERIAL O_2 SATURATION

Graph constructed from data in column C, Part I.



Contributor: Stone, Daniel J.

Method K = intermittent sampling method of Kety [13]. S = continuous sampling method of Scheinberg [14]. Values in parentheses are ranges, estimate "b" unless otherwise indicated (cf. Introduction).

		No. of		Brain		
	continued					
16	Diabetes mellitus, acidosis	8	K	45(35-55)	2.7	11
17	Diabetes mellitus, coma	6	K	65(38-92)	1.7(1.3-2.1)	11
18	Hypoglycemia (in schizophrenia)	7	K	62(51-73)	2.6(1.9-3.3)[1]	12

/1/ 1.9(0.9-2.9) in coma

Contributor: Gordan, Gilbert S.

References. [1] Kennedy, C 1956. Progress in neurobiology. Harper and Brothers, New York. v. 1, p. 230. [2] Gordan, G. S 1956 Hormones and the aging process. Academic Press, New York. p. 299. [3] Fazekas, J F. 1955 Am. J Med. 18 477. [4] Fazekas, J. F. 1953. J. Am. Geriat. Soc. 1:836. [5] Gordan, G. S. 1956. Recent Progr. Hormone Res. 12:153. [6] Gordan, G. S. 1951. Ann. N. York Acad. Sc. 54:575. [7] Sensenbach, W 1954. J. Clin Invest 33:1434. [8] Scheinberg, P. 1950. Ibid. 29:1010. [9] Sokoloff, L. 1953. Ibid. 32:202. [10] Schieve, J. F. 1951. Ibid. 30:1527. [11] Kety, S. S. 1949. Ibid. 27:500. [12] Kety, S. S. 1948. Am. J. Psychiat 104:765. [13] Kety, S. S., and C. F. Schmidt. 1948. J. Clin. Invest. 27:476. [14] Scheinberg, P., and E. A Stead, Jr. 1949. Ibid. 28 1163.

127. RENAL FUNCTION IN CONDITIONS OF NORMAL, LOW, AND HIGH CARDIAC OUTPUT: MAN

Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Variable	Normal		Chronic Rheumatic Heart Disease (Low Output)		Chronic Cor Pulmonale (High Output)		Reference
		No. of Subjects	Value	No. of Subjects	Value	No. of Subjects	Value	
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Glomerular filtration rate, ml/min	14	145(119-174)	8	68(50-94)	10	76(28-134)	1
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible] output, %	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Renal arterio-venous O_2 difference, vol %	3	2.1(1.9-2.5)	5	3.8(3.2-4.4)	2	2.1(2.0-2.25)	1

Contributor: Helm, Robert A.

References: [1] Davies, C. E., and J. A. Kilpatrick. 1951. Clin. Sc., Lond. 10:53. [2] McMichael, J., and E. P. Sharpey-Schafer. 1944. Brit. Heart J. 6 33.

128. RIGHT HEART CATHETERIZATION VALUES IN ACQUIRED CARDIAC DISEASES, AT REST AND DURING EXERCISE: MAN

Exercise: pedalling (bicycle ergometer) at approximately 40 revolutions per minute for a period of approximately 5 minutes. Values in parentheses are ranges, estimate "c" (cf. Introduction).

	Variable	Condition	Normal	Mitral Stenosis	Mitral Insufficiency	Aortic Stenosis	Left Ventricular Failure[1]
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Number of subjects		25	24	20	8	8
2	Right atrial pressure (mean), mm Hg	Rest	6(2-10)	6(2-17)	8(2-16)	5(1-15)	5(-2 to +8)
3	Pulmonary artery pressure (mean), mm Hg	Rest	17(10-22)	40(18-72)	44(19-78)	35(10-61)	32(15-46)
4		Exercise	24(17-33)	65(35-112)	54(28-80)		49(29-63)
5	Pulmonary artery "wedge" pressure (mean), mm Hg	Rest	12(8-15)	24(12-46)	23(14-39)	23(8-37)	
6		Exercise		34(23-47)	32(21-42)		
7	Cardiac index, L/min/sq m	Rest	3.5(2.8-6.3)	2.6(1.5-3.9)	2.6(1 6-3.9)	2.7(2.2-4.2)	2 9(2.1-3.7)
8		Exercise	5.7(4.8-7.7)	3.5(1.8-5.5)	3.2(2.0-4.1)		2 7(1.9-4.3)
9	Pulmonary arteriolar resistance, dynes sec cm^{-5}	Rest	67(44-110)	350(90-1110)	200(40-490)		
10		Exercise		550(40-2000)	300(70-590)		
11	Total pulmonary resistance, dynes sec cm^{-5}	Rest	189(90-290)	750(320-1870)	600(440-990)		514(260-1070)
12		Exercise	162(110-230)	1050(420-3200)	750(390-1180)		839(362-1420)

/1/ Excluded are diseases (such as hyperthyroidism, arterio-venous fistula, beriberi) resulting in left ventricular failure, with so-called "high output" failure.

Contributor: Witham, A. Calhoun

References: [1] Anderson, M W., and E. H. Wood. 1957. Clinical cardiopulmonary physiology. Grune and Stratton, New York. [2] Ball, D., H. Kopelman, and A. C. Witham. 1952. Brit. Heart J. 14.363. [3] Hickam, J. B., and W. H. Cargill. 1948. J. Clin. Invest. 27.10.

	Specification	Animal	Graves' Disease[1]	Simmonds' Disease[2]	Myxedema[3]	Addison's Disease[4]	Diabetes[5]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Blood (concluded)							
53	pH	Man					-6	G,7
54		Dog				-		F,60,61
55	Total blood count	Man			-	+		E,25,38
56		Cat				+		F,62
57		Dog		-		+		D,52,57,63,F,55,54,64
58		Rabbit				+		F,62
59		Rat		-	-	+		D,55,57,65,E,66;F,62
60		Rat				-		F,66
61	RBC count	Man					+	G,6
62	RBC life span	Man			-			E,67
63		Rat		0				D,68
64	O_2 capacity	Man				+		F,4
65		Dog				+		F,64
66	CO_2 capacity	Cat				-		F,69
67		Dog				-		F,60,64
68	Arterial O_2 saturation	Man					0	F,32
69	Venous O_2 saturation	Man					+	F,32
70	Glucose (fasting)	Man	+	-	0	-	+	C,17,43,70,D,2,71;E,3,72;F,4,17,49,G,5-7,28
71		Cat				-	+	F,73,74,G,6
72		Dog		-		-	+	D,9,75,F,76,G,6
73		Monkey		-			+	D,75,G,6
74		Pig					+	G,6
75		Rabbit		-				D,75
76		Rat		-		-		D,c,F,77,78
77	Insulin	Man		-				D,79
78		Dog					-	G,80
79		Rat		-				D,79
80	Cholesterol	Man	-	0	+		+	C,81,82,D,83,E,25,81,82,G,6,7,84,85
81		Man					0	G,5,28,86
82		Dog		-		+	+	D,87,F,88,G,89-91
83		Dog				0		F,92
84		Monkey			0			E,93
85		Rabbit		-				D,11
86		Rat			+	0		E,94,F,88
87	Phospholipids	Man	-				+	C,81,82,G,6,84,85
88		Dog		-			+	D,87,G,c
89	Total fatty acids	Man					+	G,c
90		Dog		-			+	D,87,G,c
91	β-Hydroxybutyric acid	Man					+	G,6
92		Dog					+	G,91
93	Creatine	Man			-			E,25
94	Creatinine	Cat				-		F,73
95	Glycogen	Man					-	G,28
96	Thiocyanate	Man					+	G,95
97	Insulin sensitivity	Man	-	+	+	+	-	C,E,3,D,2,71;F,4,17,G,6
98		Man			0		-6	E,96,G,7
99		Cat			+			E,97-99
100		Dog		+	+	+	-	D,100,101;E,97-99,F,76,G,c
101		Monkey		+				D,101-103
102		Rabbit		+				D,101
103		Rat		+		+		D,101,F,f
104	Glucose tolerance	Man	+	+	+	+	+	C,3,17,104,D,2,105;E,3,25,F,4,G,5-7,28
105		Man			0			E,72
106		Dog		+		+	+	D,106,F,c,G,107

/1/ Hyperthyroidism. /2/ Hypopituitarism. /3/ Hypothyroidism /4/ Hypoadrenalism. /5/ Hypoinsulinism. /6/ In ketosis.

130. EFFECT OF ENDOCRINE DISORDERS: MAMMALS

Symbols: (+) = increase, (-) = decrease, (0) = no change.

	Specification	Animal	Graves' Disease[1]	Simmonds' Disease[2]	Myxedema[3]	Addison's Disease[4]	Diabetes[5]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
1	Body temperature	Man	+	-	-	-	-	C,1,D,2;E,3,F,4,G,5
2		Man					-[6]	G,6,7
3		Cat				-		F,8
4		Dog		-		-		D,9,10,F,8
5		Rabbit		0				D,11
6		Rat		-	-	-		D,12;E,13;F,14-16
7	Activity	Man	-	-	-	-		C,E,17;D,2;F,4
8		Cat				-		F,8
9		Dog		-		-		D,9,F,8
10		Rat					-	G,18
11	Spontaneous running	Rat	-	-	-	-		C,19,20;D,21;E,20, 22;F,23
12		Rat			0			E,19
13	Forced activity	Rat				-		F,24
	Heart							
14	Size	Man	+	-	+	-	+	C,4,17;D,f,E,17,25, 26;F,4,27;G,28
15		Rat				-		F,29
16	Rate	Man	+	-	-		+	C,30,D,8,E,25,31;G, 5,6,32
17		Dog		-				D,b
18		Monkey		-				D,b
19	Cardiac output	Man	+	-	-	-		C,33-35,D,36;E,25, 33,34,F,c
20		Dog		-		-		D,36,F,37
21		Monkey		-				D,b
	ECG							
22	Amplitude[7]	Man			-			E,17,25,38
23	Height	Man				-		F,17
24	ST segment	Man					-	G,39
25	PR interval	Man				+		F,17,27
26	QT interval	Man				+	+	F,17,27;G,39
	Pressure							
27	Blood	Man	+[8]	-	+	-[9]	-	C,4;D,2;E,17,25,26; F,4,17;G,5,6,32
28		Man					-[6]	G,7
29		Dog		-		-		D,9,40,41;F,37
30		Rat				-		F,42
31	Pulse	Man	+	-	-			C,d,D,b,E,38
32		Dog		-				D,b
33	Capillary permeability	Man			+			E,43
34		Dog				+		F,44
35		Rat				+		F,44
36	Circulation time	Man	-	+	+			C,3;D,f,E,3,38
37	*Prothrombin time*	Dog					-	G,45
	Blood							
38	Volume	Man	+	-	-	-	-[6]	C,46,D,f,E,47,48;F, 49;G,6,7
39		Cat			-			E,48
40		Dog				-		F,29
41		Rat		-				D,50
42		Rat		0				D,51
43	Hemoglobin	Man		-	-	-	+	D,2;E,3,F,17,G,32
44		Man					+[6]	G,6
45		Cat				+		F,8
46		Dog		-		+		D,52,F,53
47		Dog				0		F,54
48		Rat		-		-		D,50,55,56,F,57
49	Hematocrit	Man		-	-	+	+	D,f,E,3,F,4,G,32
50		Cat				-		F,8
51		Dog				+		F,53,58
52		Rat		-	0	-		D,50,55,56,E,59,F,57

/1/ Hyperthyroidism. /2/ Hypopituitarism. /3/ Hypothyroidism. /4/ Hypoadrenalism. /5/ Hypoinsulinism.
/6/ In ketosis. /7/ T wave inverted. /8/ Systolic and mean, right ventricular. /9/ Systolic and diastolic.

	Specification	Animal	Graves' Disease[1]	Simmonds' Disease[2]	Myxedema[3]	Addison's Disease[4]	Diabetes[5]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
	Blood electrolytes (concluded)							
160	Urea	Man		0			+6	D,2,G,6
161		Cat				+		F,73,74
162		Dog				+		F,53,58
163		Rat			+	+		E,139,F,8
164	Uric acid	Man			[illegible]		0	G,118
165		Cat				-		F,73
166		Dog				0		F,53,54
	Blood flow							
167	Brain	Man	+		-			C,f;E,34
168		Rat				-		F,140
169	Lung	Man	+					C,33
170	Muscle	Man	+					C,141,142
171	Peripheral artery	Man					-	G,5
172		Man					-6	G,7,32
173	Skin	Man	+		-			C,141,142,E,142
174	Kidney	Man			-	-		E,25,143,F,49
	Plasma							
175	Volume	Man	+	-	-	-	-6	C,17;D,f,E,17,38,F,4,G,144
176		Dog				-		F,29
177		Rat		-				D,56
178	CO_2 combining power	Man					-6	G,6,7
179		Dog					-6	G,112
180	Proteins	Man	-		+	+	+	C,3,17,E,3,25,26,F,4,G,32
181		Cat				+		F,74,145
182		Dog		-		+		D,146,F,145
183		Dog				0		F,54
184		Rat		-				D,59
185	Total proteins	Man					0	G,147
186		Rat		-				D,56
187	Total lipids	Man					+	G,6
188		Dog					+	G,89,91
189		Dog					-	G,148
190	Choline	Dog					-	G,149
191	Cholinesterase activity	Man					+	G,150
192	2,3-Diphosphoglyceric acid	Man					0	G,151
193	Albumin	Man					-	G,147
194	β-Globulin	Man					+	G,147
195	Amino acid nitrogen	Dog					+	G,91
196	Acetoacetic acid	Man					+6	G,91
197	Plasma flow, renal	Dog		-				D,40
	Serum							
198	Albumin	Man			-			E,25
199		Dog		-		-		D,59;F,145
200		Rat		-	0			D,E,59
201	Total globulin	Dog		+		+		D,59,F,145
202		Rat		+	+			D,E,59
203	γ-Globulin	Man			+			E,25
204	α-Globulin	Man			-			E,25
205	Lipoprotein	Dog					0	G,90
206		Dog					+6	G,90
207	Phospholipids	Man			+			E,25,81,82
208	Glucuronic acid	Man					+	G,152
209	[illegible]	[illegible]	+				+	G,153
[illegible]	[illegible]	[illegible]				+		C,17;F,154
[illegible]	[illegible]	[illegible]					+	G,5,28,32
[illegible]	[illegible]	[illegible]	+				+	G,28,155
[illegible]	[illegible]	[illegible]			+		+11	C,f,E,17,G,f

[illegible] sm. /3/ Hypothyroidism. /4/ Hypoadrenalism. /5/ Hypoinsulinism.

130. EFFECT OF ENDOCRINE DISORDERS: MAMMALS (Continued)

	Specification	Animal	Graves' Disease[1]	Simmonds' Disease[2]	Myxedema[3]	Addison's Disease[4]	Diabetes[5]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
107	Glucose tolerance (concluded)	Monkey		+				D,102
108		Rat				0		F,78
109	Blood electrolytes Bicarbonate	Man					-[6]	G,d
110		Cat				-		F,69
111		Dog				-	-[6]	F,61,108,G,f
112	Calcium	Man	0	0	0	+		C,4;D,2;E,4,38;F
113		Cat				-		F,73
114		Dog		0		+	-	D,109-111;F,53,9 G,112
115		Rat				-		F,113
116	Chloride	Man	0		0	-	-	C,F,4;E,4,25,G,11
117		Man			+		-[6]	E,38;G,6
118		Cat				-		F,115
119		Dog		0		-	-	D,110,111,F,53,10 G,112
120		Rat				-		F,c
121	Copper	Man	0			+		C,116;F,117
122	Glutathione	Man					0	G,118
123		Man					-[6]	G,119
124		Dog		0				D,120
125	Iron	Man				0		F,121
126		Man				-		F,117
127	Lactic acid	Dog		0		+	-	D,122;F,123;G,124, 125
128		Dog		+				D,124
129	Magnesium	Man	+		-		-	C,E,126,127,G,114, 128,129
130		Cat				+		F,115
131		Dog		0			-	D,110,G,112
132		Dog		+				D,111
133	Non-protein nitrogen	Man		0		+	+[6]	D,2;F,17;G,6
134		Cat				+		F,130
135		Dog				+		F,53
136		Rat		+	0	+		D,E,59;F,8
137	Phosphorus	Man	0	0	0	+		C,E,4,D,2;F,49
138		Cat		-		+		D,131,F,73,74
139		Dog		0		+	+	D,109,110;F,60,61; G,124,132
140		Dog		-		0		D,133;F,54
141		Rat		-				D,134
142	Potassium	Man	0	+	0	+	0	C,F,4,D,2,E,4, 25,G, 135
143		Man					+	G,114
144		Man					-[6,10]	G,7
145		Cat				+		F,115,130
146		Dog		0		+		D,110,F,108
147		Monkey		+				D,102
148		Rat				+		F,42
149	Protein-bound iron	Man	+	-	-			C,E,3,D,f
150	Sodium	Man	0	-	0	-	-	C,4;D,2;E,4,25;F,4, 136,G,114
151		Man			-		-[6]	E,137,G,6
152		Cat				-		F,115
153		Dog		0		-	-	D,110,111;F,108,G, 112
154		Monkey		-				D,102
155		Rat				-		F,8
156	Sulfate	Man				+		F,49
157		Dog				+		F,61,138
158	Sulfur	Dog				+		F,138
159	Total base	Man					-[6]	G,6

/1/ Hyperthyroidism. /2/ Hypopituitarism. /3/ Hypothyroidism. /4/ Hypoadrenalism. /5/ Hypoinsulinism. /6/ In ketosis. /10/ During insulin treatment.

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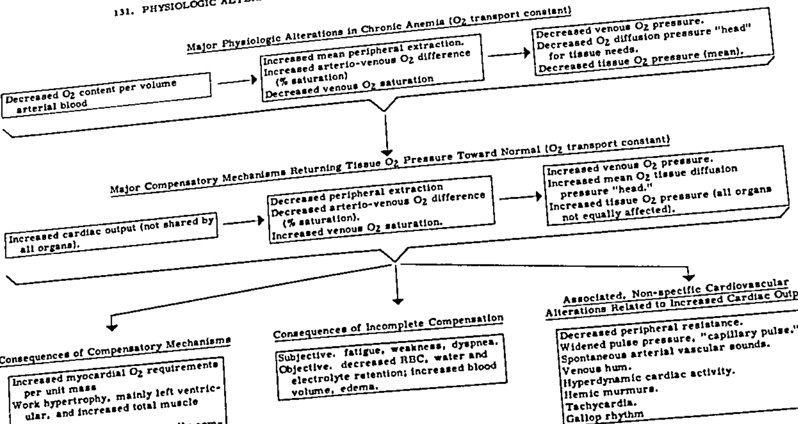
	Specification	Animal	Graves' Disease[1]	Simmonds' Disease[2]	Myxedema[3]	Addison's Disease[4]	Diabetes[5]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
214	Respiratory rate	Man	+	-	-		+	C,156;D,1;E,31;G,5,6
215		Man					+[6]	G,7
216	Respiratory quotient	Cat					-	G,157
217		Dog					-	G,91,124
218		Rat				-		F,16
219	O_2 consumption (BMR)	Man	[illegible]	-	-	-	+[6]	D,2,71;E,4;F,4,27;G,158
220		Cat				0	+	F,159;G,160
221		Dog		-				D,9,161,162
222		Guinea pig	+					C,163,164
223		Rat		-	-	-		D,12,165,166;E,165,F,16,165,167
224	Vital capacity	Man	-					C,168
225	Ventilatory response to exercise	Man	+					C,169
	Ventilatory equivalent							
226	Resting	Rat			-			E,170
227	Active	Rat			-			E,170
228	Coefficient of pulmonary elastic resistance	Man	0					C,169
229	Mean inspiratory non-elastic resistance	Man	0					C,169

/1/ Hyperthyroidism. /2/ Hypopituitarism. /3/ Hypothyroidism. /4/ Hypoadrenalism. /5/ Hypoinsulinism.
/6/ In ketosis.

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131. PHYSIOLOGIC ALTERATIONS AND COMPENSATORY MECHANISMS IN CHRONIC ANEMIA: MAN



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131. CARDIOVASCULAR AND PULMONARY SYMPTOMS OF ANEMIA: MAN AND OTHER ANIMALS

	Variable	Chronic Anemia[1,2] Uncomplicated	Reference	Chronic Anemia[1,2] With Congestive Heart Failure	Reference	Acute Anemia Large Hemorrhage[3]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Vessels	Hyperkinemia, pulsating neck vessels, collapsing pulse, capillary pulsation, Duroziez' and Traube's phenomena, venous hum (bruit de diable).	1	Engorged neck veins.	5	Pallor, cyanosis, coldness of extremities, absence of pulsation over large arteries.	6
		Dilated and tortuous retinal veins.[4]	2			Ischemic optic neuritis with pale edematous discs, attenuated retinal arterioles and mildly distended and tortuous veins, hemorrhages and exudates near the discs, edema of retina in macular areas, and subsequent optic atrophy.[5]	7
		Capillary dilatation and stasis leading to ischemic necrosis of tissues [4]	3			Visceral ischemia; visceral congestion, edema, and petechial hemorrhages if death occurs despite blood transfusions.	8
		Thickening of the small and medium arteries by intimal proliferation, thrombosis.[4]	4				
2	Heart	Dilatation, hypertrophy and increased weight, fatty degeneration with yellow subendocardial streaks at venous end of capillaries perpendicular to the fibers of the trabeculae and papillary muscles (tiger lily heart).	9-11	Flabby myocardium, obliterative endarteritis of coronary and pericardial vessels, vacuolization of sarcoplasm, interstitial edema, increased size and weight, dilatation, hypertrophy [4]	4	*Firm musculature.*	27
		Interstitial edema, polymorphonuclear infiltration, myocardial degeneration, vacuolated sarcoplasm, Zenker's degeneration.[4]	4			Diffuse focal or confluent areas of myocardial necrosis, chiefly in the subendocardium of the *left ventricle and especially* the papillary muscles.	28
		Increased interarterial coronary anastomosis	12			Scattered areas of fatty infiltration and acute necrosis in both the ventricles and interventricular septum, most frequently beneath the endocardial surface and in the papillary muscles [6]	29
		Pericardial lemon-yellow or hemorrhagic effusion.	13,14				
		Flabby musculature	11				
		Cor pulmonale [4]	15				
3	Impulse	Forceful apical thrust.	16	Forceful apical thrust, may be diffuse and wavy.	17		
		Diffuse and wavy.	2,17,18				
		Pulmonary diastolic tap.	2,17,18				
4	Borders	Enlarged.[7]	19-21	Enlarged.	17		
5	Sounds	M_1 accentuated, P_2 accentuated or split	22	M_1 accentuated, P_2 accentuated or split.	17	Disappearance of sounds.	6
		Gallop rhythm.	2,19	Gallop rhythm.	26	Tic-tac sounds if there is tachycardia.	1
6	Murmurs	Systolic: pulmonary, mitral, aortic.	5,9,10, 19,22	Systolic: pulmonary, mitral.	17,26		
		Diastolic or presystolic mitral, pulmonary, aortic.	5,9,23-25	Diastolic: mitral	17,26		
7	Thrills	Systolic or diastolic	5	Systolic	17		

/1/ Since effects have no linear relationship to the severity of anemia, no quantitative values are given [5]. /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent, serious abnormalities do not occur until hemoglobin is less than 7 grams. [31] /3/ A liter or more, data include observations during hemorrhagic shock. /4/ Observations made in sickle cell anemia, many of the effects are peculiar to sickle cell disease only, and the possibility exists that associated histologic and pathologic findings are unrelated to anemia per se [6]. /5/ Usually observed after repeated hemorrhage [7]. /6/ Experimental observations in dogs. /7/ Enlargement usually reversible, but may persist in cases of long duration [20].

132. GENERAL SYMPTOMS OF ANEMIA: MAN AND OTHER ANIMALS

Chronic Anemia[1,2]				Acute Anemia	
Uncomplicated	Reference	With Congestive Heart Failure	Reference	Large Hemorrhage[3,4]	Reference
(A)	(B)	(C)	(D)	(E)	(F)
Palpitation, dyspnea, edema.	1-3	Palpitation, edema, dyspnea (at rest), orthopnea.	3	Angina.	12-14
Intermittent claudication	2,4			Oliguria, anuria, acute tubular failure.	15
Gross hematuria.	5				
Angina.	2,4,6-9	Cardiac asthma.	10,11	Increased respiratory rate and amplitude, sweating, fainting, twitching of extremities, unconsciousness.	16,17
Circulatory death.	10,11				
				Dimness or loss of vision.	18,19
				Yawning, desire to defecate or urinate, rotation of eyes.	17
				Waves of tingling over body, restlessness, carpal spasms, hyperventilation.	16
				Manifestations of circulatory and respiratory failure.	20

/1/ Since effects have no linear relationship to the severity of anemia, no quantitative values are given [3].
/2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent; serious abnormalities do not occur until hemoglobin is less than 7 grams. [21] /3/ A liter or more; data include observations during hemorrhagic shock. /4/ May precipitate congestive failure [12,22], or myocardial infarction [23].

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134. ELECTROCARDIOGRAPHIC, BALLISTOCARDIOGRAPHIC, AND ROENTGENOGRAPHIC FINDINGS IN ANEMIA: MAN AND OTHER ANIMALS

	Method	Chronic Anemia[1,2] Uncomplicated	Reference	Chronic Anemia[1,2] With Congestive Heart Failure	Reference	Acute Anemia Large Hemorrhage[3]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Electrocardiographic[4]	Low, flat, or inverted T.	1-4	Low, flat, or inverted T.	12	Low, flat, or inverted T.	13-16
		Notched T.[5]	3	Depressed ST segment.	12	Depressed ST segment.	13,14, 16
		Depressed RT junction and ST segment.	1,3,4	Low, flat, or inverted P.	12	Low, wide, or slurred QRS.	16
		Low, flat, or inverted P.	1,5,6	Decreased QRS amplitude.	12		
		Tall, peaked, notched P.[5]	3	QT interval more often increased.	1		
		Decreased QRS amplitude.	1,4	Increased PR interval.	12		
		Large, diphasic QRS.[5]	3	Left ventricular hypertrophy pattern.	12		
		Increased QT interval.	1-3	Premature beats.	12		
		Increased PR interval	2,3,7-10	Atrial tachycardia.	12		
		Incomplete right bundle branch block.[5]	11				
		Left ventricular hypertrophy pattern.	1,7,11				
		Left ventricular strain.	3,12				
		Right axis deviation.[5]	2				
		Nodal tachycardia, nodal escape, and arteriovenous dissociation.[5]	3				
		Premature beats	1-3,8				
		Atrial fibrillation.[5]	5				
		Parasystole.	12				
		Atrial bigeminy	12				
		Isolated T inversion in precordial leads	12				
2	Ballistocardiographic[4]	Minimal respiratory variation of I and J, increased amplitude of systolic complexes I, J, K, abnormal pattern.[6]	17	Pattern may be normal[7], increased systolic complexes, tall L and N.	17	Minimal respiratory variation, normal or reduced I and J, J slopes off gradually into the small L wave instead of returning quickly to the base line, absent K, large H.	17
		Large systolic complexes with normal or abnormal pattern, tall or bifid H, plateau-like I valley, slurred or notched I-J and J-K segments, broad or bifid J, fused H-J, short, absent, or notched K, tall N, L, totally bizarre complexes of low amplitude, grade 1-4 abnormal patterns	18	Large systolic complexes with normal or abnormal pattern, tall H, L, N, slurred or notched I-J and J-K segments, notched or bifid J, short or absent K, totally bizarre complexes of low amplitude, grade 1-4 abnormal patterns.	18		
3	Roentgenographic Vessels	Increased aortic and pulmonary artery pulsations	19	Prominent vascular shadows	19		
		Dilated pulmonary artery	6,19	Dilated pulmonary artery.	19		
		Prominent vascular shadows	20				

/1/ Since effects have no linear relationship to severity of anemia, no quantitative values are given [1]. /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent, serious abnormalities do not occur until hemoglobin is less than 7 grams [28] /3/ A liter or more, data include observations during hemorrhagic shock. /4/ In some patients with chronic anemia (either uncomplicated or with congestive failure), and in the absence of any other cardiovascular disease, an increase in pattern abnormality may occur after improvement of anemia, or abnormality may persist after cure of anemia. /5/ Observations made in sickle cell anemia; many of the effects are peculiar to sickle cell disease only, and the possibility exists that associated histologic and pathologic findings are unrelated to anemia per se [6] /6/ Pattern may be normal, in anemia with cardiac damage, abnormal pattern often apparent only during normal expiration. [17] /7/ Marked abnormal curves may appear when anemia is corrected in some subjects known to have heart disease, transient abnormal pattern may appear when hemoglobin is rapidly raised in severe anemia and the heart is severely damaged by anoxia [17]

	Variable	Chronic Anemia[1,2]				Acute Anemia	
		Uncomplicated	Reference	With Congestive Heart Failure	Reference	Large Hemorrhage[3]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
8	Lungs	Obliterative endarteritis and thrombosis of small and medium vessels, polymorphonuclear infiltration, infarction, pleural effusion.[4]	4	Edema, obliterative endarteritis and thrombosis of pulmonary arterioles, bilateral pleural effusion.[4]	4		
		Capillary dilatation and stasis, bronchopneumonia, atelectasis.[4]	3	Signs of congestion, pleural effusion.	5		
				Pulmonary edema.	4,17		
		Congestion.	4,5				
		Edema.[4]	2,4,25, 27				
		Pneumonia.[4]	30				

/1/ Since effects have no linear relationship to the severity of anemia, no quantitative values are given [5]. /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent; serious abnormalities do not occur until hemoglobin is less than 7 grams. [31] /3/ A liter or more; data include observations during hemorrhagic shock. /4/ Observations made in sickle cell anemia; many of the effects are peculiar to sickle cell disease only, and the possibility exists that associated histologic and pathologic findings are unrelated to anemia per se [b].

Contributors: (a) Sanghvi, L. M., (b) Wintrobe, M. M.

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135. HEMODYNAMIC AND PULMONARY EFFECTS OF ANEMIA: MAN AND OTHER ANIMALS

	Variable	Chronic Anemia[1,2] Uncomplicated	Chronic Anemia[1,2] With Congestive Heart Failure	Acute Anemia Small Hemorrhage[3]	Acute Anemia Large Hemorrhage[4]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Cardiac function					
1	Output	Increased	Increased or normal	Slightly decreased[5]	Decreased	B,1-9,C,6,8,10,D,11-13,E,14-19
2		May be normal	Increased or decreased	May be normal		B,6,20,C,6,D,13,17,19
3	Stroke volume	Increased		Normal[5]	Decreased	B,4,9,D,19,E,18
4	Rate	Increased	Increased	Slightly increased[6]	Increased[7]	B,1,3,5,C,6,D,12,13,17;E,11,19,21
5		Normal or slow	Increased or decreased			B,6,20,22,C,6
					Decreased	B,4,E,18
6	Work	Normal				B,7
7		May increase[8]				
	Utilization coefficient					
8	Pyruvate, lactate, glucose				Decreased	E,18
	Utilization, absolute					
9	Pyruvate				Decreased	E,18
10	Lactate				Increased	E,18
11	Glucose				Decreased or normal	E,18
	Blood					
12	Total volume	Decreased	May increase		Decreased	B,5,8,23,C,10,E,17,21,24
13	Viscosity	Decreased			Normal	B,5,25,E,26
14					Decreased, may increase terminally	E,27
15	Proteins	May decrease	Often decreased		Immediately decreased[9]	B,28,C,10,E,24,29,30
16	Plasma volume	Increased	Increased		Decreased	B,23,C,10,E,17,24,29
17	Capillary permeability	Increased in severe cases	Increased		Increased, may increase terminally	B,C,28,E,27
	Blood pressure					
18	Systolic	Decreased[10]	Decreased	Decreased[5]	Decreased	B,5,9,31,C,32,D,17,19,E,17,19,33
19		May be normal			Normal or increased	B,34,E,35
20		May increase				B,36
21	Diastolic	Decreased	Decreased	Decreased[11]	Decreased	B,5,9,31,C,32,D,17,E,17,19
22	Mean	Decreased	Decreased		Decreased	B,9,C,32,E,17,18
23	Pulse	Increased	Increased	Decreased	Decreased	B,3,6,9,C,32,D,E,36
24	Right atrium	Normal	Increased	Decreased	Decreased	B,1,C,8,D,12,13,17,E,11,17
25	Pulmonary artery	Normal, may increase	May increase		Decreased	B,7,C,37,E,38
26	Pulmonary arterio-capillary gradient	Normal, may increase	May increase			B,7,C,37

/1/ Effects have no linear relationship to the severity of anemia, and therefore no numerical values can be given [6] /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent, serious abnormalities do not occur until hemoglobin is less than 7 grams [3]. /3/ Effects of small hemorrhage are increased respiratory rate and occasionally orthostatic syncope [61] /4/ A liter or more, data include observations during hemorrhagic shock /5/ Overcompensation may cause increase [40]. /6/ May be normal in supine position, but increased when standing [19] /7/ Bradycardia, particularly during fainting [11, 19, 33] /8/ Observations made in sickle cell anemia, many of the effects are peculiar to sickle cell disease only, and the possibility exists that associated histological and pathological findings are unrelated to anemia per se [b] /9/ May be little change [33], increased later [27] /10/ Hypertension may occur after recovery [4, 9] /11/ May be normal in supine position, but decreased when standing [19]

	Method	Chronic Anemia[1,2] Uncomplicated	Reference	Chronic Anemia[1,2] With Congestive Heart Failure	Reference	Acute Anemia Large Hemorrhage[3]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
	Roentgenographic (concluded)						
4	Heart	Hyperactive cardiac pulsations.	19	Enlargement.	1	Decreased size and oscillations.	27
		Enlarged silhouette.	21				
		Generalized, globular, left ventricular or right ventricular enlargement.	1				
		Straightening of left border.	22				
		Prominent conus.	1				
		Mitralized configuration.	1,5,23, 24				
		Enlargement of left atrium accompanying general cardiac enlargement.	6				
		Pericardial effusion.[8]	25				
5	Lungs	Increased bronchovascular markings.	19,20	Congestion, unilateral or bilateral pleural effusion.	1		
		Irregular patchy infiltrations, symmetrical nodular densities (hemosiderosis), infarction.[5]	20	Encysted pleural effusion.	26		
				Pericardial effusion	19		
		Massive consolidation.[5]	20				

/1/ Since effects have no linear relationship to severity of anemia, no quantitative values are given [1]. /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent; serious abnormalities do not occur until hemoglobin is less than 7 grams [28]. /3/ A liter or more, data include observations during hemorrhagic shock. /5/ Observations made in sickle cell anemia; many of the effects are peculiar to sickle cell disease only, and the possibility exists that associated histologic and pathologic findings are unrelated to anemia per se [b]. /8/ Only with pericardial inflammation, or in heart failure [b].

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[illegible]

Variable	Chronic Anemia (a,b): Uncomplicated[1]	Chronic Anemia (a,b): With Congestive Heart Failure	Acute Anemia: Small Hemorrhage[3]	Acute Anemia: Large Hemorrhage[4]	Reference
(A)	(B)	(C)	(D)	(E)	(F)
Pulmonary function (continued)					
O_2 consumption					
57 Total	Normal			Normal	B,1,7-9,B,17,19
58 Cardiac	Increased or [illegible]			Decreased	B,42,E,16,[illegible]
59 Blood lactic acid	Increased			Increased[14]	B,1,E,23
60 Vital capacity		Decreased[15]	Decreased		C,[illegible],D,53
61 [illegible]	Normal				B,54
62 Physiologic dead space	Normal				B,54
63 Reserve air		Decreased[15]			C,1
64 Respiratory minute volume		Increased[15]		Increased	C,1,7,E,5[illegible]
65 Residual air		Increased[15]			C,1
66 Alveolar-arterial O_2 pressure gradient	Increased				B,56
67 Arterial O_2	Normal			Normal	B,1,E,55
68 pressure	May increase				B,56
69 Pulmonary arterial O_2 pressure	Increased				B,54
70 Peripheral venous O_2 pressure	Increased				B,54
71 Pulmonary elastic resistance coefficient	Normal				B,57
72 Mean inspiratory non-elastic resistance	Normal				B,57
Renal function					
73 Effective plasma flow	Decreased[8,16]	Decreased		Decreased	B,9,49,53,C,9, E,49
74 Glomerular filtration rate	Decreased[8,16]	Usually no decrease		Decreased	B,9,49,53,C,9, E,49
75 Tubular excretory capacity	Decreased				B,49,53
76 Salt and water excretion	Decreased				B,44,53

/1/ Effects have no linear relationship to the severity of anemia, and therefore no numerical values can be given [b]. /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent; serious abnormalities do not occur until hemoglobin is less than 7 grams [3]. /3/ Effects of small hemorrhage are increased respiratory rate and occasionally orthostatic syncope [61]. /4/ A liter or more; data include observations during hemorrhagic shock. /8/ Observations made in sickle cell anemia; many of the effects are peculiar to sickle cell disease only, and the possibility exists that associated histological and pathological findings are unrelated to anemia per se [b]. /14/ Hyperventilation may cause alkalemia [62]. /15/ In minimal or early congestive heart failure [b]. /16/ May be normal in children, but decreases with age [58].

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References: [1] Blumgart, H. L., and M. D. Altschule. 1948. Blood, N. Y. 3:329. [2] Blumgart, H. L.,

	Variable	Chronic Anemia[1,2]		Acute Anemia		
		Uncomplicated	With Congestive Heart Failure	Small Hemorrhage[3]	Large Hemorrhage[4]	Reference
	(A)	(B)	(C)	(D)	(E)	(F)
	Blood pressure (concluded)					
27	Mesenteric artery				Decreased	E,39
28	Hepatic artery				Decreased	E,39
29	Venous	Almost always normal	Increased	Slightly decreased	Decreased or normal	B,1,6;C,6;D,4 E,19
30		May increase				B,6,8
31	Inferior vena cava				Decreased	E,39
32	Portal vein				Immediately decreased, then increased	E,39
	Blood flow					
33	Coronary	Increased			Decreased	B,41,42;E,18,43
34	Pulmonary	Increased			Decreased	B,1;E,44
35	Cutaneous	Decreased		Decreased	Decreased	B,10,D,E,40
36	Skeletal	Increased in forearm		Decreased	Increased during fainting	B,45,D,40,E,11
37	Cerebral	Increased			Decreased	B,46;E,47
38	Mesenteric				Decreased	E,39
39	Hepatic	Increased			Increased	B,36,E,48
40	Renal	Decreased	Decreased		Decreased	B,9,49,50;C,9,50,E,16,48
	Vascular resistance					
41	Total	Decreased	Decreased[12]	Normal	Normal or increased	B,1,3,5,7,9,42,C,10,D,E,17
42				May increase	May decrease in shock	D,12,E,17
43				Decreased during fainting		D,11
44	Coronary	Decreased			Decreased	B,42,E,18,43
45	Pulmonary	Normal			Inconsistent change	B,7;E,42
46	Cutaneous	Increased		Increased	Increased	B,51;D,E,40
47	Cerebral	Decreased			Decreased	B,46,E,47
48	Mesenteric				Immediately increased, then decreased	E,39
49	Hepatic				Increased	E,39
50	Renal	Increased	Increased			B,C,9
	Pulmonary function					
	O_2 utilization coefficient[13]					
51	Systemic	Increased			Increased	B,5,7-9,22,E,18
52	Cardiac	Increased in severe cases			Normal	B,41,E,18,42
	Arterio-venous O_2 difference					
53	Systemic	Decreased			Increased	B,3,5,9,E,17,18
54	Coronary	Decreased			Normal	B,41,E,18
55					Decreased	B,42
56	O_2 dissociation curve	Displaced to right				B,52

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	Variable	Chronic Anemia[1,2]		Acute Anemia		Reference
		Uncomplicated	With Congestive Heart Failure	Small Hemorrhage[3]	Large Hemorrhage[4]	
	(A)	(B)	(C)	(D)	(E)	(F)
	Pulmonary function (concluded)					
	O_2 consumption					
57	Total	Normal			Normal	B,1,7-9,E,17,18
58	Cardiac	Increased in severe cases			Decreased	B,41,E,18,42
59	Blood lactic acid	Increased			Increased[14]	B,1;E,18
60	Vital capacity		Decreased[15]	Increased		C,1;D,53
61	0.5 sec expiratory capacity/vital capacity x 100	Normal				B,54
62	Physiologic dead space	Normal				B,54
63	Reserve air		Decreased[15]			C,1
64	Respiratory minute volume		Increased[15]		Increased	C,1,7;E,55
65	Residual air		Increased[15]			C,1
66	Alveolar-arterial O_2 pressure gradient	Increased				B,56
67	Arterial O_2	Normal			Normal	B,1,E,55
68	pressure	May increase				B,56
69	Pulmonary arterial O_2 pressure	Increased				B,54
70	Peripheral venous O_2 pressure	Increased				B,54
71	Pulmonary elastic resistance coefficient	Normal				B,57
72	Mean inspiratory non-elastic resistance	Normal				B,57
	Renal function					
73	Effective plasma flow	Decreased[8,16]	Decreased		Decreased	B,9,49,58,C,9,E,59
74	Glomerular filtration rate	Decreased[8,16]	Usually no decrease		Decreased	B,9,49,58,C,9;E,59
75	Tubular excretory capacity	Decreased				B,49,58
76	Salt and water excretion	Decreased				B,49,60

/1/ Effects have no linear relationship to the severity of anemia, and therefore no numerical values can be given [6]. /2/ Moderate abnormalities appear when hemoglobin level is between 8 and 9 grams per cent, serious abnormalities do not occur until hemoglobin is less than 7 grams [3] /3/ Effects of small hemorrhage are increased respiratory rate and occasionally orthostatic syncope [61] /4/ A liter or more, data include observations [illegible] shock /8/ Observations made in sickle cell anemia, many of [illegible] and the possibility exists that associated histological and patho [illegible] /14/ Hyperventilation may cause alkalemia [62] /15/ In mink [illegible] be normal in children, but decreases with age [58].

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APPENDIXES

APPENDIX I FORMULAS AND CALCULATIONS PROPOSED FOR CLINICAL USE

I Cardiac Output Determined by the Fick Principle. [1]

1. $$\text{Cardiac output (ml/min)} = \frac{O_2 \text{ uptake (ml/min)} \times 100}{\text{arterial } O_2 \text{ content (vol \%)} - \text{mixed venous } O_2 \text{ content (vol \%)}}$$

The Fick principle employs the following three adjuncts to determine cardiac output (1) right heart catheterization to obtain a mixed venous blood sample from the right ventricle or pulmonary artery, (2) direct puncture of the femoral artery for obtaining arterial blood, (3) collection and measurement of expired air in a Tissot spirometer or a Douglas bag.

II. Calculations of Blood Flows. [2-6]

Modifications of the Fick principle are used to quantitate flow rates.

1. $$\text{Systemic blood flow (ml/min)} = \frac{O_2 \text{ uptake (ml/min)} \times 100}{\text{peripheral arterial } O_2 \text{ content (vol \%)} - \text{mixed venous } O_2 \text{ content (vol \%)}}$$

   ↓ Volume of blood passing through the periphery per minute.

2. $$\text{Pulmonary arterial flow (ml/min)} = \frac{O_2 \text{ uptake (ml/min)} \times 100}{\text{pulmonary venous } O_2 \text{ content (vol \%)} - \text{pulmonary arterial } O_2 \text{ content (vol \%)}}$$

   ↓ Volume of blood passing through the pulmonic valve into the pulmonary artery per minute.

3. $$\text{Effective pulmonary flow (ml/min)} = \frac{O_2 \text{ uptake (ml/min)} \times 100}{\text{pulmonary venous } O_2 \text{ content (vol \%)} - \text{mixed venous } O_2 \text{ content (vol \%)}}$$

   ↓ Volume of mixed venous blood which, after having returned to the right atrium, ultimately reaches the pulmonary capillaries.

III. Calculations of Shunts [7]

1. Overall (net) shunt, left ⟶ right = pulmonary artery flow - systemic flow
2. Overall (net) shunt, right ⟶ left = systemic flow - pulmonary artery flow
3. Total left ⟶ right shunt = pulmonary capillary flow - effective pulmonary flow
4. Total right ⟶ left shunt = systemic flow - effective pulmonary flow

IV Formulas Used in Cardiac Catheterization. [7-16]

Abbreviations CO = cardiac output, ml/sec; PA_m = pulmonary artery mean pressure, mm Hg; PA_{sm} = pulmonary arterial systolic mean pressure, mm Hg; PC_m = pulmonary capillary mean pressure, mm Hg, LA_{dm} = left atrial diastolic mean pressure, mm Hg, LV_{dm} = left ventricular diastolic mean pressure, mm Hg, RA_m = right atrial mean pressure [illegible] RA_{sm} = right atrial systolic mean pressure, [illegible] mm Hg, RV_{sm} = right ventricular systolic [illegible] pulmonary flow, L/min/sq m body surface [illegible] Factors and constants. 1332 = factor for [illegible] recting anomalies of discharge through the [illegible] during the diastolic filling period, and for converting mm Hg to cm H_2O; 5 = assumed end diastolic pressure of left ventricle, 13.6 = specific weight of Hg, 1 055 = specific gravity of blood

By the application of Poiseuille's law (resistance = $\frac{\text{pressure gradient}}{\text{rate of flow}}$), many formulas have been derived for calculation of vascular resistances and valve areas.

1. $$\text{Total pulmonary resistance} = \frac{PA_m \times 1332}{CO} = \text{dynes sec cm}^{-5}$$

2. $$\text{Pulmonary arteriolar resistance} = \frac{(PA_m - PC_m) \times 1332}{CO} = \text{dynes sec cm}^{-5}$$

3. $$\text{Valvular blood flow} = CO \times \frac{\text{duration of cardiac cycles (measured)}}{\text{duration of diastoles of same cardiac cycles (measured)}}$$

4. Mitral valve resistance $= \dfrac{(LA_{dm} - LV_{dm}) \times 1332}{CO \times \dfrac{\text{duration of total cardiac cycles (measured)}}{\text{duration of diastoles of same cardiac cycles (measured)}}} =$ dynes sec cm^{-5}

5. Tricuspid valve resistance $= \dfrac{(RA_{dm} - RV_{dm}) \times 1332}{CO \times \dfrac{\text{duration of total cardiac cycles (measured)}}{\text{duration of diastoles of same cardiac cycles (measured)}}} =$ dynes sec cm^{-5}

6. Pulmonary valve resistance $= \dfrac{(RV_{sm} - PA_{sm}) \times 1332}{PBF \times \dfrac{\text{duration of total cardiac cycles (measured)}}{\text{duration of systolic ejections of same cardiac cycles (measured)}}} =$ dynes sec cm^{-5}

7. Mitral valve flow (ml/sec) $= \dfrac{\text{cardiac output in ml/min}}{\text{duration of the sum of diastolic periods in sec/min}}$

8. Mitral valve area[1] $= \dfrac{MVF}{31\sqrt{PC_m - 5}} = \dfrac{MVF}{31\sqrt{LA_{dm} - LV_{dm}}}$

9. Right ventricular work[2] $= \dfrac{13.6\,(PF \times 1.055)\,(PA_{sm} - RA_m)}{1000} =$ kg m/min/sq m body surface area

/1/ Formulas for calculating area of pulmonary, tricuspid, and aortic valves, and for calculating size of an atrial or ventricular septal defect, or for measuring diameter of a patent ductus arteriosus, may be found in references 7 and 12. /2/ Left ventricular work may be estimated by substituting brachial or femoral for pulmonary, arterial systolic mean pressure, and left for right, atrial mean pressure.

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APPENDIX II. REGRESSION EQUATIONS

I. Relations Between Stroke Volume, Left Ventricular Work, and Various Aspects of Blood Pressure, Determined by Blood Perfusion Method Simulating Systole in Cadavers. [1-4]

Data for regression equations were secured from cadavers perfused by blood at necropsy. Stroke volume was measured in the syringe, work was estimated by integration of the product of pressure and flow values at each instant, and blood pressures were obtained from a capacitance manometer attached to a needle in the femoral artery.

Abbreviations: SV = stroke volume, ml; W = left ventricular work, g-m; FSP = femoral systolic pressure, mm Hg; FDP = femoral diastolic pressure, mm Hg; FPP = femoral pulse pressure, mm Hg, FMP = femoral mean pressure, mm Hg; ASP = aortic systolic pressure, mm Hg; AMP = aortic mean pressure, mm Hg; A = age, yr; SA = body surface area, sq m; PWV = pulse wave velocity, m/sec; Q = cross section area of the root of the aorta, sq cm; ml = milliliter, g-m = gram meters.

	Regression Equation (A)	Standard Deviation (B)
1	SV = 48.1 - 0.38 PWV	14.3 ml
2	SV = 50.5 - 0.09 A	14.3 ml
3	SV = 19.3 + 15.66 SA	14.0 ml
4	SV = 57.3 - 0.18 FDP	13.9 ml
5	SV = 28.0 + 0.30 FPP	13.9 ml
6	SV = 51.6 - 0.07 A - 0.28 PWV	14.3 ml
7	SV = 15.9 + 0.03 A + 16.49 SA	14.0 ml
8	SV = 16.3 + 21.13 SA - 1.14 PWV	13.8 ml
9	SV = 55.6 - 0.20 FDP + 0.43 PWV	13.8 ml
10	SV = 74.2 - 0.22 FDP - 0.22 A	13.6 ml
11	SV = 26.4 - 0.22 FDP + 20.24 SA	13.2 ml
12	SV = 14.8 + 0.29 FPP + 8.41 SA	11.8 ml
13	SV = 38.6 + 0.32 FPP - 0.29 A	11.7 ml
14	SV = 42.6 + 0.49 FPP - 3.55 PWV	9.6 ml
15	SV = 47.4 + 0.43 FPP - 0.40 FDP	8.9 ml
16	SV = 26.4 + 0.42 FPP - 0.42 FDP + 13.95 SA	8.5 ml
17	SV = 54.3 + 0.55 FPP - 0.32 FDP - 2.60 PWV	7.5 ml
18	SV = 91.0 + 0.54 FPP - 0.57 FDP - 0.61 A	5.9 ml
19	SV = 94.4 + 0.54 FPP - 0.58 FDP - 0.62 A - 1.60 SA	5.9 ml
20	SV = 54.7 + 0.57 FPP - 0.44 FDP - 0.31 A + 13.80 SA - 2.30 PWV	5.2 ml
21	SV = 90.97 + 0.73 FPP - 0.57 (FDP + 1/3 FPP) - 0.61 A	5.9 ml
22	SV = 90.97 + 0.82 FPP - 0.57 (FDP + 1/2 FPP) - 0.61 A	5.9 ml
23	SV = 90.96 + 0.92 FPP - 0.57 (FDP + 2/3 FPP) - 0.61 A	5.9 ml
	When Z_1 = FMP = 1/2 (FSP + FDP) then	
24	$SV = 20 + \frac{45}{Z_1}(FPP)$	11.5 ml
25	$SV = 47 + \frac{59}{Z_1}(FPP) - 0.58\,A$	9.3 ml
	When Z_2 = 1/3 (2 FSP + FDP) then	
26	$SV = 18 + \frac{53}{Z_2}(FPP)$	11.6 ml
27	$SV = 45 + \frac{71}{Z_2}(FPP) - 0.59\,A$	9.4 ml

	Regression Equation (A)	Standard Deviation (B)
28	$SV = 50 - 0.7\ (Q \times 10)$	14.2 ml
29	$SV = 45 - 0.003\ (\frac{Q}{PWV} \times 10^2)$	14.4 ml
30	$SV = 40 + 0.14\ (FPP)\ (Q)\ (10^{-1})$	14.0 ml
31	$SV = 40 + 0.10\ \frac{(FPP)\ (Q)}{PWV}$	14.0 ml
32	$SV = -13.4 + 20.8 \sqrt{\frac{FPP}{PWV}}$	9.3 ml
33	$SV = -11 + 0.05\ FPP + 1.08\ (\frac{1}{PWV})\ (10^2)$	8.9 ml
	Standard deviation of the values for stroke volume, found in the various experiments, about their own mean.	14.4 ml
34	$W = -8.83 + 0.93\ SV\ (AMP)\ (13.6)\ (10^{-3})$	10.9 g-m
35	$W = -6.37 + 0.89\ SV\ (FMP)\ (13.6)\ (10^{-3})$	12.0 g-m
	Let X_4 = SV estimated by equation 18	
36	$\therefore W = -1.67 + 0.83\ X_4\ (FMP)\ (13\ 6)\ (10^{-3})$	14.9 g-m
	Let X_5 = SV estimated by equation 25	
37	$\therefore W = -7.96 + 1.22\ X_5\ (FMP)\ (13.6)\ (10^{-3})$	16.5 g-m
38	$W = 1.1 + 1.13\ FPP$	18.3 g-m
39	$W = 0.54 + 68.4\ \frac{FPP}{A}$	16.6 g-m
40	$W = -9 + 0.78\ FMP$	26.2 g-m
41	$W = 44\ 9 + 1.21\ FPP - 0\ 79\ A$	15 3 g-m
42	$W = 51.5 + 1\ 13\ FPP + 31\ 48\ SA$	16 6 g-m
43	$W = 15.5 + 1.20\ FPP - 0.65\ A + 12\ 9\ SA$	15.1 g-m
44	$W = 13.6 + 1.30\ FPP - 3.12\ PWV$	17.2 g-m
45	$W = 15\ 16 + 1\ 13\ FPP - 2\ 22\ Q$	16.7 g-m
46	$W = 29.57 + 1\ 31\ FPP - 3\ 38\ PWV - 2.35\ Q$	15 4 g-m
	Standard deviation of the values for work, found in the various experiments, about their own mean	32.2 g-m

II. Relations Between Stroke Volume, Left Ventricular Work, and Various Aspects of Blood Pressure, Determined by Arm Auscultatory Method [1-6]

Abbreviations: SV = stroke volume, ml, W = left ventricular work, g-m; SP (aus) = auscultatory systolic pressure, mm Hg; DP (muff) = auscultatory diastolic pressure estimated as the level of muffling of sounds; DP (dis) = auscultatory diastolic pressure estimated as the level of disappearance of sounds, BSP, BDP, BPP and RSP, RDP, RPP = brachial systolic, brachial diastolic, brachial pulse, radial systolic, radial diastolic, and radial pulse pressures, respectively, mm Hg, FMP = femoral mean pressure, mm Hg, A = age, yr.

	Regression Equation (A)	Standard Deviation (B)
1	$BSP = -6\ 08 + 1.04\ SP\ (aus)$	10.3 mm Hg
2	$BDP = 4.86 + 0.83\ DP\ (muff)$	7.7 mm Hg
3	$BPP = 8.56 + 1.01\ [SP\ (aus) - DP\ (muff)]$	10 9 mm Hg
4	$SV = 93 + 0.54\ [SP\ (aus) - DP\ (muff)] - 0.47\ DP\ (muff) - 0.61\ A$	
5	$RPP = 14\ 54 + 0.94\ [SP\ (aus) - DP\ (dis)]$	3 9 mm Hg
6	$RSP = 16.62 + 1.00\ SP\ (aus)$	12 5 mm Hg
7	$RDP = -3.2 + 1.03\ DP\ (dis)$	12 5 mm Hg

	Regression Equation (A)	Standard Deviation (B)
8	SV = 101 + 0.5 [SP (aus) - DP (dis)] - 0.59 DP (dis) - 0.61 A	
9	SV = 100 + 0.5 [SP (aus) - DP (dis)] - 0.6 DP (dis) - 0.6 A	
	Let X_6 = an estimate of SV by equation 4 and	
	Let Y_6 = an estimate of FMP as follows.	
10	FMP = -0.61 + 0.52 [SP (aus) + 0.42 DP (muff)]	
11	$\therefore W = -1.67 + 0.0113 X_6Y_6$	
	Let X_4 = an estimate of SV by equation 8 and	
	Let Y_4 = an estimate of FMP as follows:	
12	FMP = 3.21 + 0.5 [SP (aus) + 0.52 DP (dis)]	
13	$\therefore W = -1.67 + 0.0113 X_4Y_4$	

III. Relation Between Stroke Volume and Amplitude of Certain Waves of the High-Frequency Ballistocardiogram. [7]

Data for regression equations were secured from experiments on cadavers perfused with blood while lying on a high-frequency ballistocardiograph. Ballistocardiograms show influence of size and age of subjects; abnormal tracings were excluded.

Abbreviations: SV = stroke volume, ml, Ht = height of subject, cm, Wt = weight of subject, kg; A = age of subject, yr, SA = body surface area, sq m, C = duration of cardiac cycle, sec, I and J = areas of I and J waves from base line of record, mm sec, when calibration of record is such that 280 grams displaces the base line 1 centimeter

	Regression Equation (A)	Standard Deviation (B)
1	$SV = 11 + 0.27\ Ht\sqrt{(2I + J)}\sqrt{C}$	9 ml
2	$SV = 14 + 0.64\ Wt\sqrt{(2I + J)}\sqrt{C}$	7.9 ml
3	$SV = 11 + \frac{2700}{A}\sqrt{(2I + J)}\sqrt{C}$	7.8 ml
4	$SV = 10 + 27\ SA\sqrt{(2I + J)}\sqrt{C}$	7.7 ml
5	$SV = 15 + 38.5\sqrt{(2I + J)}\sqrt{C}$	9.9 ml
6	$SV = -27 + 42\sqrt{(2I + J)}\sqrt{C} + 24\ SA$	8.0 ml
7	$SV = 31 + 45\sqrt{(2I + J)}\sqrt{C} - 0.49\ A$	8.0 ml
8	$SV = 4 + 45\sqrt{(2I + J)}\sqrt{C} + 15\ SA - 0.29\ A$	7.5 ml
	Standard deviation of the values for stroke volume, in 51 experiments, about their own mean.	14.6 ml

IV. Empirical Normal Standards for High-Frequency Ballistocardiograms. [8]

Normal subjects tested after 15-minute rest on the high-frequency ballistocardiograph, and never within 2 hours of a meal. The instrument was calibrated statically so that a force of 280 grams displaced the light spot 1 centimeter.
Abbreviations: I and J = the altitude or areas of waves typical of the largest wave of the respiratory cycle, I_2 and J_2 = the altitude or areas of waves typical of the smallest waves of the respiratory cycle, PR = pulse rate, beats/min; MBP = mean blood pressure, mm Hg; mm sec = millimeter second.

	Aspect Studied	Measurement Analyzed	Subjects		Results		
			Age, yr	No. and Sex	Mean	Standard Deviation	S. D. %[1]
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	Wave altitudes	$\sqrt{I + J + I_2 + J_2 \text{ mm}}$	20-39	56♂	5.4 mm	0.58 mm	10 7
2				48♀	4.4 mm	0.49 mm	11.2
3	Wave altitudes x PR	$\sqrt{I + J + I_2 + J_2 \text{ mm}}$ x PR	20-39	56♂	385	52.5	13.7
4				48♀	318	55.5	17.4
5	Wave altitudes	$\sqrt{I + J + I_2 + J_2 \text{ mm}}$	20-49	106♂	5.3 mm	0.66 mm	12.5
6				88♀	4.5 mm	0.62 mm	13.8
7	Wave areas	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}}$	20-49	103♂	0.83 mm sec	0.11 mm sec	13.3
8				81♀	0.67 mm sec	0.07 mm sec	10.4
9	Wave areas x PR	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}}$ x PR	20-49	101♂	81	12 2	15.0
10				81♀	68	12.4	18.3
11	Wave areas x MBP	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}}$ x MBP	20-49	98♂	122	16.0	14.1
12				81♀	89	12.6	14.2

/1/ Standard deviation as % of mean.

V. Normal Standards for Amplitude of Ballistocardiograms, Allowing for the Effect of Age. [8]

Normal subjects, ranging from 20-49 years of age, tested after 15-minute rest on the high-frequency ballistocardiograph, and never within 2 hours of a meal The instrument was calibrated statically so that a force of 280 grams displaced the light spot 1 centimeter.
Abbreviations: I and J = the altitude or areas of waves typical of the largest waves of the respiratory cycle; I_2 and J_2 = the altitude or areas of waves typical of the smallest waves of the respiratory cycle; A = age, yr, PR = pulse rate, beats/min, mm sec = millimeter second

	Aspect Studied	Subjects, No. and Sex	Regression Equation	Standard Deviation about the Regression	S. D. %[1]
	(A)	(B)	(C)	(D)	(E)
1	Wave altitudes	105♂	$\sqrt{I + J + I_2 + J_2 \text{ mm}} = -0\ 04\ A + 6.7$	0.60 mm	11.3
2		87♀	$\sqrt{I + J + I_2 + J_2 \text{ mm}} = -0.03\ A + 5.5$	0.53 mm	11 8
3	Wave areas	101♂	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}} = -0.0071\ A + 1.4$	0.142 mm sec	12 1
4		81♀	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}} = -0.0042\ A - 1.07$	0 085 mm sec	9.0
5	Wave area x PR	101♂	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}} \times PR = -0.608\ A + 102.3$	11.0	13.6
6		81♀	$\sqrt{I + J + I_2 + J_2 \text{ mm sec}} \times PR = -0.495\ A + 82.4$	11.6	17 0

/1/ Standard deviation about the regression as % of mean.

VI. Relation Between Various Aspects of the Femoral Pulse Wave and Aspects of Left Ventricular Function. [9]

Data for regression equations were secured from blood perfusion experiments in which systole was simulated in cadavers. Femoral pulse wave secured by a needle in the femoral artery.
Abbreviations MEV = maximum ejection velocity, ml/sec (the integral of the preceding accelerations), AMP = aortic mean blood pressure, mm Hg; FPP = femoral pulse pressure, mm Hg; Z = maximum slope of femoral pulse wave front, mm Hg/sec, PWV = pulse wave velocity, m/sec; SV = stroke volume, ml; FASA = adjusted systolic area of femoral pulse wave, mm Hg/sec (the area above a straight line intersecting the pressure record at the beginning and end of ejection), FMP = femoral mean blood pressure, mm Hg.

	Regression Equation (A)	Standard Deviation about the Regression (B)	Standard Deviation of MEV x AMP(10⁻²), MEV, and SV about its own mean (C)
1	$MEV \times AMP(10^{-2}) = 63.8 + 0.29\,Z$	65	166
2	$MEV \times AMP(10^{-2}) = -11.0 + 5.43\,FPP$	67	160
3	$MEV = 158 + 1.36\,\frac{Z}{PWV}$	59	109 ml/sec
4	$MEV = 10 + 3.16\sqrt{\frac{Z}{PWV} \times 100}$	53	109 ml/sec
5	$SV = 22 + 350\,\frac{FASA}{FMP}$	9.3 ml	14.7 ml
6	$SV = -2.7 + 190\sqrt{\frac{FASA}{FMP}}$	8.6 ml	14.7 ml
7	$SV = 18.6 + 30\,\frac{FASA}{PWV}$	7.7 ml	14.7 ml
8	$SV = -5.4 + 55\sqrt{\frac{FASA}{PWV}}$	7.4 ml	14.7 ml

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References [1] Starr, I., T. G. Schnabel, Jr., and R. L. Mayock 1953. Circulation, N. Y. 8:44. [2] Starr, I., T. G. Schnabel, Jr., S. I. Askovitz, and A. Schild. 1954. Ibid. 9:648. [3] Starr, I., S. I. Askovitz, W. Feder, and A. Schild. 1955. Ibid. 12:1005. [4] Starr, I. Unpublished. [5] Hagan, C., and J. Bordley. 1941. Bull. Johns Hopkins Hosp. 69:526 [6] Steele, J. M. 1941. J. Mount Sinai Hosp. N. York 8:1042. [7] Starr, I. 1955. J. Appl. Physiol. 8:115 [8] Starr, I. 1955. Circulation, N. Y. 11:914. [9] Starr, I. 1958. Ibid. 17:589.

APPENDIX III. EMPIRICAL NORMAL STANDARDS FOR ULTRA-LOW FREQUENCY BALLISTOCARDIOGRAMS

Recorded are normal displacement, velocity, and acceleration of the human body during the cardiac cycle, when the body is free to move in space. Mean values are given, with the standard deviation in parentheses.

Data on Subjects

	Subjects, No. and Sex	Age yr	Height in.	Body Weight kg	Body and Platform Weight kg	Body Surface Area sq m	Pulse Rate beats/min
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	50♂	29.6 (4.8)	70.72 (2.32)	76.25 (10.15)	83.05 (10.15)	1.929 (0.137)	65.3 (8 8)
2	50♀	28.8 (7.1)	65.12 (2.41)	58.98 (8.36)	65.78 (8.36)	1.635 (0.132)	71.1 (9.4)

I Standards for Amplitude.

1. Displacement.

Abbreviations: ″IJ = vertical distance from tip of I wave to tip of J wave, ″JM = vertical distance from tip of J wave to tip of M wave; μ = microns measuring actual movement of subject in space.

	Subjects	″IJ		″JM		″IJ/″JM
		μ	g-cm	μ	g-cm	%
1	50♂ 20-39 yr	37.73 (10.33)	309.4 (88.51)	86.80 (22.50)	722.0 (225.4)	44.4 (12.8)
2	50♀ 20-39 yr	26.55 (8 70)	174.0 (59.4)	68.84 (18.80)	453.3 (130.8)	39.8 (12.2)

2. Velocity.

Abbreviations: ′I and ′J = velocity equivalent to deflection of these waves from the base line; ′HI and ′IJ = velocity equivalent to the vertical distance between wave tips.

	Subjects	′I		′J		′HI		′IJ	
		mm/sec	g-m/sec	mm/sec	g-m/sec	mm/sec	g-m/sec	mm/sec	g-m/sec
1	50♂ 20-39 yr	0.66 (0.15)	54.4 (13.2)	0.66 (0.13)	54.6 (12.9)	0.78 (0.16)	64.8 (14.2)	1.31 (0.22)	108.9 (20.8)
2	50♀ 20-39 yr	0.48 (0.13)	32.1 (8 3)	0.57 (0.10)	37.7 (8.2)	0.57 (0 12)	37 5 (8.6)	1.07 (0.19)	69.9 (14.5)

3. Acceleration.

Abbreviations: H, I, and J = force equivalent to displacement of the tip of these waves from the base line, g = force in grams.

	Subjects	H	I	J
		g	g	g
1	50♂ 20-39 yr	94.0 (33)	226.2 (56.3)	239.2 (49.7)
2	50♀ 20-39 yr	52.6 (24)	146 0 (42.5)	177.3 (51.0)

APPENDIX III. EMPIRICAL NORMAL STANDARDS FOR ULTRA-LOW FREQUENCY BALLISTOCARDIOGRAMS (Concluded)

Standards for Time.

1. Displacement.

Abbreviations: Q-"G_0, Q-"H, Q-"I, Q-"J, and Q-"M = time in seconds between the Q wave of the electrocardiogram and the peak of the corresponding wave of the displacement ballistocardiogram when recorded simultaneously. "G_0 = onset of G wave.

	Subjects	Q-"G_0	Q-"H	Q-"I	Q-"J	Q-"M
1	50♂ 20-39 yr	-0.064[1] (0.018)	0.087[2] (0.022)	0.134 (0.013)	0.228 (0.020)	0.440 (0.025)
2	50♀ 20-39 yr	0.079[3] (0.024)	0.086[4] (0.016)	0.128 (0.012)	0.212 (0.016)	0.433 (0.029)

/1/ Value for 32 subjects. /2/ Value for 49 subjects. /3/ Value for 25 subjects. /4/ Value for 46 subjects.

2. *Velocity.*

Abbreviations: Q-'H, Q-'I, Q-'J, Q-'L, and Q-'M = time in seconds between the Q wave of the electrocardiogram and the peaks of the corresponding waves of the velocity ballistocardiogram when recorded simultaneously; 'I_t and 'J_t = duration of the 'I and 'J waves on the base line.

	Subjects	Q-'H	Q-'I	Q-'J	Q-'L	Q-'M	'I_t	'J_t
1	50♂ 20-39 yr	0.115 (0.013)	0.182 (0.015)	0.305 (0.021)	0.426[1] (0.021)	0.511[2] (0.029)	0.098 (0.019)	0.215 (0.029)
2	50♀ 20-39 yr	0.109 (0.013)	0.170 (0.008)	0.282 (0.026)	0.422 (0.021)	0.490 (0.028)	0.086 (0.017)	0.229 (0.020)

/1/ Value for 49 subjects /2/ Value for 44 subjects.

3. Acceleration.

Abbreviations: Q-H, Q-I, Q-J, Q-L_0, Q-L, Q-M, Q-N = time in seconds between the Q wave of the electrocardiogram and the peaks of the corresponding wave of the acceleration ballistocardiogram when recorded simultaneously. L_0 = small negative wave usually preceding the L wave, I_t and J_t = duration in seconds of the I and J waves on the base line

	Subjects	Q-H	Q-I	Q-J	Q-L_0	Q-L	Q-M	Q-N	I_t	J_t
1	50♂ 20-39 yr	0.101 (0.014)	0.154 (0.014)	0.235 (0.020)	0.390 (0.021)	0.418 (0.023)	0.451 (0.024)	0.557[1] (0.031)	0.064 (0.012)	0.127 (0.013)
2	50♀ 20-39 yr	0.099 (0.013)	0.150 (0.012)	0.216 (0.017)	0.387 (0.023)	0.415 (0.021)	0.447 (0.024)	0.544[1] (0.032)	0.057 (0.011)	0.116 (0.016)

/1/ Value for 48 subjects

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Reference Scarborough, W R., E E Folk, III, P M Smith, and J. H Condon. 1958. Am J. Cardiology 2 613.

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Asterisk (*) indicates, graph, diagram, or drawing.